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ITARY MEDICAL MANUALS

GENERAL EDITOR:
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G.C.B., M.D., F.R.C.P.

# HE AFTER-EFFECTS OF WOUNDS

AUG. BROCA

EDITED BY

R. C. ELMSLIE

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MILITARY MEDICAL MANUALS

General Editor:

Sir ALFRED KEOGH, G.C.B., M.D., F.R.C.S.

# THE AFTER-EFFECTS OF WOUNDS OF THE BONES AND JOINTS

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# THE AFTER-EFFECTS OF WOUNDS OF THE BONES AND JOINTS

BY

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WITH 112 ILLUSTRATIONS

LONDON: UNIVERSITY OF LONDON PRESS LTD.
18 WARWICK SQUARE, E.C. 4
PARIS: MASSON ET CIE
120 BOULEVARD SAINT-GERMAIN
1918



# GENERAL INTRODUCTION

The infinite variety of injuries which any war presents to the surgeon gives to military surgery a special interest and importance. The special interest and importance, in a surgical sense, of the great European War lies not so much in the fact that examples of every form of gross lesion of organs and limbs have been seen, for if we read the older writers we find little in the moderns that is new in this respect but is to be found in the enormous mass of clinical material which has been presented to us and in the production of evidence sufficient to eliminate sources of error in determining important conclusions. For the first time also in any campaign the labours of the surgeon and the physician have had the aid of the bacteriologist, the pathologist, the physiologist, and indeed of every form of scientific assistance, in the solution of their respective problems. The clinician entered upon the great war armed with all the resources which the advances of fifty years had made available. If the surgical problems of modern war can be said not to differ sensibly from the campaigns of the past, the form in which they have been presented is certainly as different as are the methods of their solution. The achievements in the field of discovery of the chemist, the physicist and the biologist have given the military surgeon an advantage in diagnosis and treatment which was denied to his predecessors, and we are able to measure the effects of these advantages when we come to appraise the results which have been attained.

But although we may admit the general truth of these statements, it would be wrong to assume that modern scientific knowledge was, on the outbreak

of the war, immediately useful to those to whom the wounded were to be confided. Fixed principles existed in all the sciences auxiliary to the work of the surgeon, but our scientific resources were not immediately available at the outset of the great campaign; scientific work bearing on wound problems had not been arranged in a manner adapted to the requirements—indeed, the requirements were not fully foreseen; the workers in the various fields were isolated, or isolated themselves, pursuing new researches rather than concentrating their powerful forces upon the one great quest.

However brilliant the triumphs of surgery may be —and that they have been of surpassing splendour no one will be found to deny—experiences of the war have already produced a mass of facts sufficient to suggest the complete remodelling of our methods of education and research.

The series of manuals, which it is my pleasant duty to introduce to English readers, consists of translations of the principal volumes of the "Horizon" Collection, which has been appropriately named after the uniform of the French soldier.

The authors, who are all well-known specialists in the subjects which they represent, have given a concise but eminently readable account of the recent acquisitions to the medicine and surgery of war which had hitherto been disseminated in periodical literature.

No higher praise can be given to the Editors than to say that the clearness of exposition characteristic of the French original has not been lost in the rendering into English.

## MEDICAL SERIES

The medical volumes which have been translated for this series may be divided into two main groups, the first dealing with certain epidemic diseases, including syphilis, which are most liable to attack soldiers, and the second with various aspects of the

neurology of war. The last word on *Typhoid Fever*, hitherto "the greatest scourge of armies in time of war," as it has been truly called, will be found in the monograph by MM. Vincent and Muratet, which contains a full account of recent progress in bacteriology and epidemiology as well as the clinical features of typhoid and paratyphoid fevers. The writers combat a belief in the comparatively harmless nature of paratyphoid and state that in the present war hæmorrhage and perforation have been as frequent in paratyphoid, as in typhoid fever. In their chapter on diagnosis they show that the serum test is of no value in the case of those who have undergone anti-typhoid or anti-paratyphoid vaccination, and that precise information can be gained by blood cultures only. The relative advantages of a restricted and liberal diet are discussed in the chapter on treatment, which also contains a description of serum-therapy and vaccine-therapy and the general management of the patient.

Considerable space is devoted to the important question of the carrier of infection. A special chapter is devoted to the prophylaxis of typhoid fever in the army. The work concludes with a chapter on preventive inoculation, in which its value is conclusively proved by the statistics of all countries in which it has been employed.

MM. Vincent and Muratet have also contributed to the series a work on *Dysentery, Cholera and Typhus* which will be of special interest to those whose duties take them to the Eastern Mediterranean or Mesopotamia. The carrier problem in relation to dysentery and cholera is fully discussed, and special stress is laid on the epidemiological importance of mild or abortive cases of these two diseases.

In their monograph on *The Abnormal Forms of Tetanus*, MM. Courtois-Suffit and Giroux treat of those varieties of the disease in which the spasm is confined to a limited group of muscles, *e.g.* those of the head, or one or more limbs, or of the abdomino-

thoracic muscles. The constitutional symptoms are less severe than in the generalized form of the disease, and the prognosis is more favourable.

The volume by Dr G. Thibierge on *Syphilis in the Army* is intended as a *vade mecum* for medical officers in the army.

Turning now to the works of neurological interest, we have two volumes dealing with lesions of the peripheral nerves by Mme. Atanassio Benisty, who has been for several years assistant to Professor Pierre Marie at La Salpêtrière. The first volume contains an account of the anatomy and physiology of the peripheral nerves, together with the symptomatology of their lesions. The second volume is devoted to the prognosis and treatment of nerve lesions.

The monograph of MM. Babinski and Froment on *Hysteria or Pithiatism and Nervous Disorders of a Reflex Character* next claims attention. In the first part the old conception of hysteria, especially as it was built up by Charcot, is set forth, and is followed by a description of the modern conception of hysteria due to Babinski, who has suggested the substitution of the term " Pithiatism," *i.e.* a state curable by persuasion, for the old name hysteria. The second part deals with nervous disorders of a reflex character, consisting of contractures or paralysis following traumatism, which are frequently found in the neurology of war, and a variety of minor symptoms, such as muscular atrophy, exaggeration of the tendon reflexes, vasomotor, thermal and secretory changes, etc. An important section discusses the future of such men, especially as regards their disposal by medical boards.

An instructive companion volume to the above is to be found in the monograph of MM. Roussy and Lhermitte, which embodies a description of the psychoneuroses met with in war, starting with elementary motor disorders and concluding with the most complex represented by pure psychoses.

## SURGICAL SERIES

When the present war began, surgeons, under the influence of the immortal work of Lister, had for more than a quarter of a century concerned themselves almost exclusively with elaborations of technique designed to shorten the time occupied in or to improve the results obtained by the many complex operations that the genius of Lister had rendered possible. The good behaviour of the wound was taken for granted whenever it was made, as it nearly always was, through unbroken skin, and hence the study of the treatment of wounds had become largely restricted to the study of the aseptic variety. Septic wounds were rarely seen, and antiseptic surgery had been almost forgotten. Very few of those who were called upon to treat the wounded in the early autumn of 1914 were familiar with the treatment of grossly septic compound fractures and wounded joints, and none had any wide experience. To these men the conditions of the wounds came as a sinister and disheartening revelation. They were suddenly confronted with a state of affairs, as far as the physical conditions in the wounds were concerned, for which it was necessary to go back a hundred years or more to find a parallel.

Hence the early period of the war was one of earnest search after the correct principles that should be applied to the removal of the unusual difficulties with which surgeons and physicians were faced. It was necessary to discover where and why the treatment that sufficed for affections among the civil population failed when it was applied to military casualties, and then to originate adequate measures for the relief of the latter. For many reasons this was a slow and laborious process, in spite of the multitude of workers and the wealth of scientific resources at their disposal. The ruthlessness of war must necessarily hamper the work of the medical scientist in almost every direction except in that of

providing him with an abundance of material upon which to work. It limits the opportunity for deliberate critical observation and comparison that is so essential to the formation of an accurate estimation of values; it often compels work to be done under such high pressure and such unfavourable conditions that it becomes of little value for educative purposes. In all the armies, and on all the fronts, the pressure caused by the unprecedented number of casualties has necessitated rapid evacuation from the front along lines of communication, often of enormous length, and this means the transfer of cases through many hands, with its consequent division of responsibility, loss of continuity of treatment, and absence of prolonged observation by any one individual.

In addition to all this, it must be remembered that in this war the early conditions at the front were so uncertain that it was impossible to establish there the completely equipped scientific institutions for the treatment of the wounded that are now available under more assured circumstances, and that progress was thereby much hampered until definitive treatment could be undertaken at the early stage that is now possible.

But order has been steadily evolved out of chaos, and many things are now being done at the front that would have been deemed impossible not many months ago. As general principles of treatment are established it is found practicable to give effect to them to their full logical extent, and though there are still many obscure points to be elucidated and many methods in use that still call for improvements, it is now safe to say that the position of the art of military medicine and surgery stands upon a sound foundation, and that its future may be regarded with confidence and sanguine expectation.

The views of great authorities who derive their knowledge from extensive first-hand practical experience gained in the field cannot fail to serve as a

most valuable asset to the less experienced, and must do much to enable them to derive the utmost value from the experience which will, in time, be theirs. The series covers the whole field of war surgery and medicine, and its predominating note is the exhaustive, practical and up-to-date manner in which it is handled. It is marked throughout not only by a wealth of detail, but by clearness of view and logical sequence of thought. Its study will convince the reader that, great as have been the advances in all departments in the services during this war, the progress made in the medical branch may fairly challenge comparison with that in any other, and that not the least among the services rendered by our great ally, France, to the common cause is this brilliant contribution to our professional knowledge.

A glance at the list of surgical works in the series will show how completely the ground has been covered. Appropriately enough, the series opens with the volume on *The Treatment of Infected Wounds*, by A. Carrel and G. Dehelly. This is a direct product of the war which, in the opinion of many, bids fair to become epoch-making in the treatment of septic wounds. It is peculiar to the war and derived directly from it, and the work upon which it is based is as fine an example of correlated work on the part of the chemist, the bacteriologist and the clinician as could well be wished for. This volume will show many for the first time what a precise and scientific method the " Carrel treatment " really is.

The two volumes by Professor Leriche on *Fractures* contain the practical application of the views of the great Lyons school of surgeons with regard to the treatment of injuries of bones and joints. Supported as they are by an appeal to an abundant clinical experience, they cannot fail to interest English surgeons, and to prove of the greatest value. It is only necessary to say the *Wounds of the Abdomen* are dealt with by Dr Abadie, *Wounds of the Vessels* by Professor Sencert, *Wounds of the Skull*

*and Brain* by MM. Chatelin and De Martel, and *Localisation and Extraction of Projectiles* by Professor Ombrédanne and R. Ledoux-Lebard, to prove that the subjects have been allotted to very able and experienced exponents.

ALFRED KEOGH.

# PREFACE

Those who, before the war, knew something about the pathology of lesions of the bones were perhaps surprised at the ideas expressed by certain people in important positions upon the comparative simplicity of fractures produced by gunshot wounds, upon their usually sufficient asepsis, enabling them, when a dressing had been applied, to be transported to a considerable distance, and contra-indicating an early operation. They were even more surprised to see these fractures, when they were found to be infected (sometimes severely so), after the removal of the dressings, treated in a totally inadequate manner; and when surgeons, after the arrest of the actual phenomena of infection and when the fractures were consolidated, showed a tendency to treat the persistent sinus as negligible, to believe that it would heal in time without difficulty, with the help, if need be, of heliotherapy, or even—oh, heresy!—of massage. They forgot the history, classical in surgery, of chronic osteomyelitis, spontaneous or traumatic in origin, with its sequestra enclosed by new bone and with its fixed contractures of joints and other complications. And so we have seen, going on indefinitely, lesions which are amenable to proper surgical intervention,

not simple curetting, which has been used and abused, but radical operations. For this reason this book, from which it may be judged that the lessons of "civil" surgery can be applied to the treatment of the wounded, seems to me to have a possible utility.

I express my thanks to Mlle. S. Cherier for the care with which she has executed, under my directions, the numerous drawings of radiographs which are here reproduced. For I hold that, for these illustrations, a diagram, drawn carefully and without prejudice, is just as valuable a document as an actual reproduction, which, I maintain, can be faked at will. And the diagram has the advantages of cheapness and of clearness. Thanks to the cheapness, which is a matter of importance at the present time, I learn with pleasure that in the other volumes of this series the method which I have introduced, with my friend Steinheil, in my *Traité de chirurgie infantile*, is being largely used. This method has the defect of requiring an author who can at the same time interpret a radiograph and instruct the draughtsman. Those who possess these two powers, fewer than might be believed, will, I hope, see that it remains in use in times of peace, and will perhaps thank me for having taught it to my friend P. Masson.

# INTRODUCTION TO ENGLISH EDITION

This volume scarcely requires an introduction. The sequelæ of which Professor Broca speaks are as frequent in England as in France; they must occur in any country that is at war. Those in England who have the treatment of the wounded in the later stages see the same chronic sinuses of the bones with sequestra and cavities, the same stiff and deformed joints as are here dealt with, and the methods of treatment advised are such as cannot be disputed by any surgeon who is experienced in the treatment of diseases of the bones.

If I might emphasise the lessons which are here to be learnt, I should express them as follows :—

1. The necessity for an appreciation of the pathology of the lesions of the bones which result from such severe injuries as gunshot wounds as a necessary preliminary to their treatment.

2. That when a sinus persists after a bone injury a careful study, clinical and radiographic, is required, with a view to the performance of an operation upon any bone cavity (with or without sequestra) which may be found; an operation of a radical nature in contradistinction to the simple removal of a palpable sequestrum, which might be the correct procedure at

an earlier stage, but which is totally insufficient in these chronic cases.

3. The necessity, in the case of a stiff joint, for a consideration of the pathological cause of the stiffness, so that the mechanical treatment is not called upon to perform impossibilities, and, what is even more important, so that a joint is not made actually worse by persistent attempts to mobilise it when it is in a state of inflammation.

4. The advisability of considering, in the case of a joint whose movements have been limited in any direction, the alignment of the bones entering into the joint. The alteration in this alignment will often explain the functional disability, and so demonstrate the uselessness of any attempts to improve it except by surgical means.

In England we have been to a large extent saved from the misuse of purely mechanical methods by the co-ordination in the orthopædic centres of mechanical methods with the surgical work, so that every patient who is undergoing mechanical treatment is at the same time under the observation of a surgeon, an ideal method of organisation.

R. C. E.

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# THE AFTER-EFFECTS OF WOUNDS OF THE BONES AND JOINTS

# The After-Effects of Wounds involving Bones and Joints

## CHAPTER I

### DEFECTS OF BONY UNION

Cases of defective union and mal-union in bones are among the frequent after-effects of gunshot fractures. Loss of bony substance of immediate or later occurrence, wounds of the soft parts preventing the methodical application of requisite apparatus, infection of the bone of a more or less chronic nature, are among the causes of the frequency with which are observed :—

1. Mal-union, the result of overlapping or angulation of fragments.
2. The excessive production of callus.
3. Delay and absence of union.

I shall not deal at length with these different lesions, because they have but little special significance in the surgery of war. There is, however, one peculiarity that I wish to emphasise, and that I shall refer to again and again without fear of repetition, *i.e.* the frequent recrudescence—spontaneous or excited by unwise interference—of the primary infection in wounds that have been healed for a long time, and to all appearances finally.

### 1. Shortening and Angulation of Fragments

Fractures, wherever they occur, become consolidated—

(1) By means of a cylindrical sheath of sub-periosteal bone, rapidly formed, and destined eventually to be partially or wholly reabsorbed. This is the "Provisional Callus of Dupuytren." (2) By the intermediate callus, which is lasting, and becomes organised gradually beneath the support of the sub-periosteal callus.

These two formations vary in their importance and persistence, according as the fracture is in a good or bad position, or is infected or uninfected.

Let us take as the first point of comparison the case of a simple fracture without any displacement, or with fully corrected displacement. The sub-periosteal sheath of small volume is reabsorbed rapidly, and only the intermediate callus persists. The bone attains, almost without perceptible difference, its former shape, length, and structure. When the reduction is imperfect it is, on the other hand, the sub-periosteal callus which becomes the more important, at times very markedly so. Indeed, if the displacement persists, the detached periosteal laminæ undergo an intense ossification so as to make up what is lacking in the attempt at union of the badly displaced fragments.

In the case of a simple lateral displacement, fig. 2 shows how the periosteal callus firmly re-establishes the continuity of the bony lever; this then becomes modelled, but only to a slight extent reabsorbed; the consolidated bone remains with more or less sharp angulation and thickened, but without shortening.

The method is the same if overlapping exists, *i.e.* elevation of the lower fragment alongside the upper, to which it remains parallel (fig. 3). But the frac-



FIG. 1.—Sub-periosteal callus in a fractured femur (child) without displacement, and of one month's standing; the space between the fragments is well shown.



FIG. 2.—Callus produced from the periosteum which has been stripped in the direction of the displacement; fracture with complete transverse displacement but without overlapping of the fragments.

tured surfaces here have lost all contact. Only the denuded surfaces of the shaft touch each other, without, however, giving support to the axis of the

limb; hence the intermediate callus is slow in formation, and very slow in reaching strength sufficient to withstand pressure in the long axis of the limb; the callus is exuberant—it may end by being double the thickness of the former bone—for a long time, if not for good; it is chiefly sub-periosteal, and shortening is inevitable (fig. 4).



FIG. 3.



FIG. 4.

FIG. 3.—Fracture with transverse displacement and overlapping of fragments. The callus has been produced by the periosteum, which has been stripped from the shaft on one side only (fig. 4).

In these cases, despite the slight degree of calcification that the relative transparence of the callus indicates, union was sufficiently firm to allow of walking.

By angulation of fragments the direct transmission of pressure from one fractured surface to the other is still more interfered with. The principal rôle is played, both originally and ultimately, by the mass of sub-periosteal bone which grows in the area of the angle formed by the two fragments; the bone, when finally united, remains crooked, the seat of union is always considerably thickened, and shortening of the limb is inevitable (fig. 5).

These two displacements are frequent, and it should be recognised that this fact has a direct bearing on the problems of treatment. It is certain, however,



FIG. 5.—Union with marked displacement and angulation of the fragments of the femur.

that they are often inevitable, the severity of the immediate infection and the extent and position of the wounds having made the proper application of splints difficult, both in the early and in the later stages of treatment.

I do not insist further on these causes, a study of

early complications not lying within the limits of this book, in which I have to deal only with lesions which are already long established and chronic.

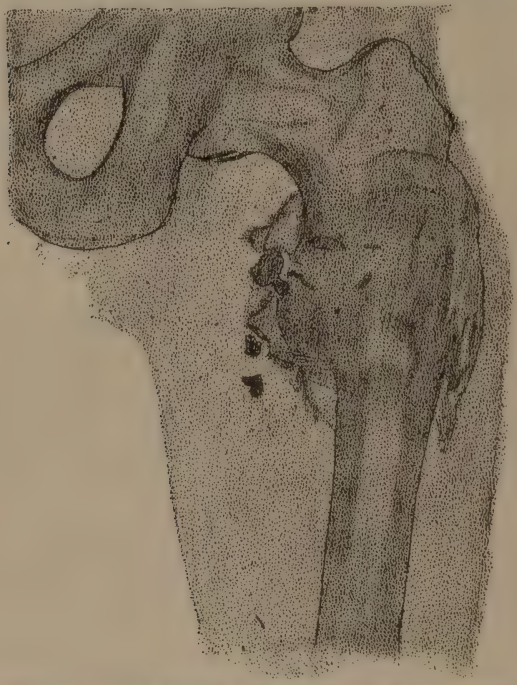


Fig. 6.—Fracture of the femur, with shortening due to neither angulation nor overlapping, but to actual loss of substance. The bullet has been broken up into fragments.

In war surgery, especially in the case of the femur, whatever care may have been expended in the mechanical treatment of the fracture, real shortening, not due to overlapping or angulation, occurs with peculiar frequency. We can do nothing in fact for the often considerable space left by a loss of bony substance (fig. 6).

If, by continuous extension, we lessen the shortening, if, while waiting, as I will describe, for the removal of sequestra we maintain the length consonant with the periosteal sheath during its process of ossification, it will be none the less true that in many cases union cannot occur without a considerable elevation of the lower fragments towards the upper. Under these conditions it is the rule, almost without exception, that osteomyelitis (acute, and later chronic) constitutes the most important factor in the problem of treatment. A similar loss of substance in one of the two bones of the forearm or leg will result, almost inevitably, in a pseudarthrosis.

In the forearm union in a bad position with the lower fragment in pronation and the upper in supination is very common. It is a lesion well known in civil surgery, and one that is very disabling from a functional point of view, for it limits more or less, sometimes to complete suppression, the movement of supination. It is well to repeat as often as the opportunity occurs that this is the almost inevitable consequence of treating a complete fracture of the forearm by immobilisation in semi-pronation, as certain writers have advised. The only method to be recommended is immobilisation of the forearm in supination. In war surgery inflammatory complications often prevent us from so doing, but whenever possible this should be our aim.

Mention should be made of ankylosis of a pair of bones together. This is a lesion of no importance in the leg but very disabling in the forearm, where it puts a definite obstacle in the way of movements of pronation and supination (fig. 7).

The surgical methods that should be employed in

these cases depend on the functional troubles resulting from these defects of union.

In the upper extremity shortening of the humerus results in but little functional inconvenience, and no treatment is required. In the lower limb, on the contrary, a shortening which exceeds 3–4 cm. is disabling, and cases occur with 10–15 cm. shortening or more. For the shortening due to loss of substance in the length of the bone the only resource is a surgical boot with thickened sole. In spite of the obstinacy of orthopædic instrument-makers, our aim should



Fig. 7.—Fracture of both bones of the forearm united in pronation, and with synostosis of the radius and ulna and sequestra. Wounded 26th January 1915; date of radiogram, 17th February 1916.

be for the patient to walk as much as possible on the flat of the sole. Of course the boot looks less inelegant if the heel alone be raised and the patient walk in equinus. But in this case the toes press with their tips against the toecap of the boot, become crowded together, and bear fatigue very badly. Where the shortening is considerable we are obliged to allow a certain obliquity to the sole, but we should always be careful to make this as little as possible in order to avoid the slipping forward of the foot.

Since the war there has come into use an arrangement which allows an independent thick cork sole to be fitted on to any shoe; hence a remarkable economy,

since with a single cork sole one can wear out several cheap shoes, orthopædic boots—properly so called—which require frequent repairing, being always expensive.

For cases of union with overlapping and angulation of the fragments, especially of the femur, osteotomy followed by reduction and fixation in good position with continuous extension is generally indicated. Excellent results are obtained, much better than by osteoclasis, which, moreover, is useless in cases of union with overlapping. The same applies to radio-ulnar synostosis; osteotomy alone can correct this deformity.

But here in war surgery a new and special factor comes into play.

In general, in civil surgery, we may say that compound fractures are, so far as orthopædic operations are concerned, almost identical with simple fractures; suppuration has usually been only moderate; the callus hardens fairly quickly and certainly after the removal of sequestra, if this has been necessary, and after waiting some months there is little liability to a recrudescence of infection.

In war surgery, however, such recrudescence is more much frequent and much more formidable. Hence orthopædic osteotomy will have to be performed late, and we should abstain from operating on cases where the deformity is only slight, but in which, under other circumstances, an operation would certainly have been indicated. This is, moreover, a fact which should be kept in mind in connection with all orthopædic operations necessitated by deformities the result of wounds in war.

In spite of this, I believe that, as a general precept,

osteotomy is better than osteoclasis. It has not been proved that recrudescence of microbic activity is less to be feared after a subcutaneous fracture, and in these bones, irregular both in shape and consistence, it would probably be impossible to perform osteoclasis with any degree of precision.

## 2. Excessive Formation of Callus

An excessive amount of callus is due to two causes: (1) imperfect reduction with overlapping of fragments, (2) excessive sub-periosteal osteogenesis.

This second cause has a maximum effect when the periosteum is infected, or at least abnormally irritated, even if infection itself is not apparent—which does not mean, however, that it may not really be present.

We see examples of this phenomenon, whatever some may say about it, in a number of simple fractures treated by open operation, with sutures, clamps and plates of various shapes and sorts. When, some time after the operation, successive X-ray plates of such cases are carefully examined, it is evident that the volume of sub-periosteal callus is abnormally great, and that it often keeps growing, little by little, for several months. This callus again remains tender to pressure, and even really painful; it has a tendency to undergo rarefaction around the foreign body that is keeping up the irritation, and secondary elimination after late suppuration is not uncommon, whilst surgical removal undertaken to relieve pain and persistent inflammation is at times necessary.

If this is the case with foreign bodies of surgical origin, whose asepsis is not always absolutely beyond

suspicion, although at first apparently sufficient, it

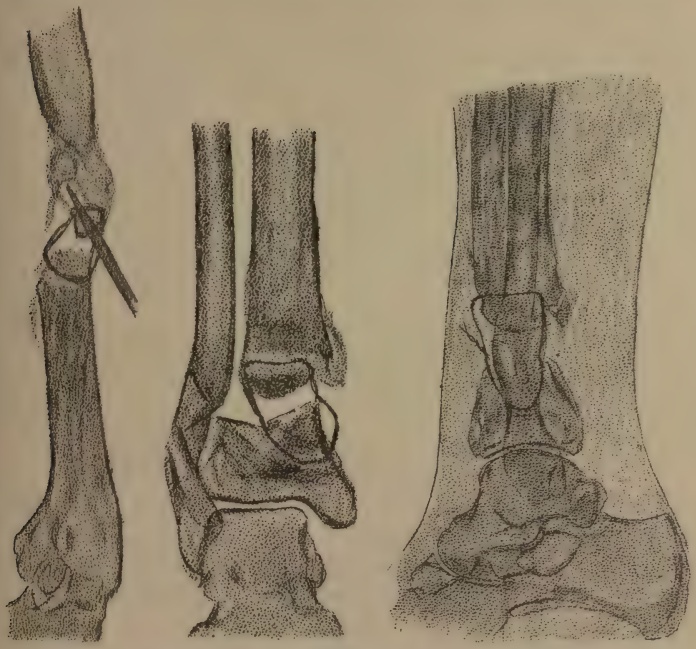


FIG. 8.—Pseudarthrosis of the humerus in a man of thirty-four, showing the existence of a ring-shaped sequestrum of the upper fragment (transfixed by a grooved probe) perforated by a silver wire which is keeping up rarefying osteitis in the lower fragment. Patient was wounded by a piece of shell, 2nd November 1914. The radiogram taken 21st January 1916. On 23rd January 1916 the wire and sequestrum were removed and the surface of the lower fragment freshened; the wound healed, but the pseudarthrosis remained, 19th May 1916.

FIGS. 9 and 10.—Antero-posterior and lateral views of a pseudarthrosis of the tibia in a man of twenty-three, wounded 26th April 1915; wiring of the bone (20th September 1915) failed—caries of both fragments and a sinus being kept up by the presence of the wire. Removal of the wire, 23rd February 1916; wound healed 1st May 1916.

will be readily understood that when, in war surgery,

foreign bodies remain embedded in bone the effect is bad even if primary suppuration has been absent, or only slight and of short duration.

This is frequently the case in certain fractures in which the covering of the bullet has been torn, and in which the lead has broken up into small pieces on striking the bone. (See fig. 6. The large foreign body is the hard covering of a bullet.) In such cases the callus produced remains for a long time hot and painful, and is only slowly absorbed and remodelled, specially if irritated by massage or untimely mobilisation.

The same thing happens, with more certainty, in the case of foreign bodies which are clearly infected, and it is on this account that, in my opinion, the various osteosynthetic operations are but rarely indicated in the immediate treatment of gunshot fractures. For the most part these pieces of metal are badly tolerated, they keep sinuses open, cause necrosis, and—more often than is usually thought—result in non-union. I shall have to return to this subject later.

Speaking generally, excessive formation of callus occurs in infected fractures, especially in those in which sinuses remain open. The second part of this book is devoted to the consideration of these.

Even in cases which are not or are no longer fistulous, excessive callus is often the result of an infection, which is latent for the time being, but susceptible for an indefinite period of giving rise to a more or less acute exacerbation of inflammation—either spontaneously, or as the result of interference.

For the moment excessive callus concerns us inasmuch as it interferes with the function of neighbour-

ing structures, which are displaced, compressed, or involved by it.

In the neighbourhood of a joint it limits the normal range of movement : we will discuss this in connection with ankylosis of joints.

Muscles, tendons, and vessels nearly always accommodate themselves fairly quickly and well to changes of relation and direction in this way imposed upon them. To liberate by operation adherent tendons seems to me to be but rarely indicated. On the other hand, the involvement of nerves which are enclosed, irritated, or stretched by callus is fairly frequent, and forms a clear indication for operation.

Excess of callus in such cases is usually but not invariably present; it does not, moreover, change the surgical indications at all, and only affects the technique of the operation to a slight extent. This consists in finding the nerve as near as possible to its point of entrance into the callus, but where it will certainly be free from it ; with chisel and mallet the nerve is then followed through the bone, in which a groove is cut along its course.

To understand properly the connection of certain nerves and certain bones is merely a matter of anatomy —*e.g.* the circumflex nerve winding round the neck of the humerus (its involvement is rare), the external popliteal around the neck of the fibula (involvement infrequent), the musculo-spiral around the middle of the humerus (involvement frequent).

The incision by which the bone is approached—most often the humerus in cases of musculo-spiral involvement—is the same as that for suture of the nerve or for freeing it from scar tissue. The only difference in the operation is that in the present case

an uninterrupted nerve-trunk is found which requires no suturing, but which does require to be protected, just as if it had been sutured, against any renewal of compression or involvement, the best method being, in my opinion, to encircle it with a flap of muscle taken from the triceps in order to remove all direct contact between nerve and bone.

The practical differentiation of the two conditions, solution of continuity requiring suture and compression requiring liberation, is, however, a matter of the greatest importance for the surgeon.

If division of the nerve is diagnosed, suture has a chance of success only when healing by first intention (I mean of the operation wound, and not of the nerve itself) is assured. The operation will therefore only be carried out when the fracture is united, and when suppuration has ceased for several weeks; of course the operation must not be too long delayed, but, in order to ensure success, early operation is to be considered a matter of the second and not of the first order of importance. Whether the division of the nerve has lasted a second or a year, the processes of degeneration in the lower portion and subsequent regeneration from the upper remain the same. There are of course many obvious reasons for operation without unnecessary delay so as to avoid as far as possible certain secondary lesions in the muscles and joints, but the chief concern is that the sutured nerve does not suppurate. I do not insist further on this point, which will be treated in a special volume.

If, on the other hand, compression or irritation of the nerve is diagnosed, it is necessary to operate at once, for ascending neuritis commences and increases quickly, and the nerve fibres must not be allowed

time to undergo further degeneration. Operation should be immediate even if the fracture is still septic, and even if it is not certain that definite sequestra have as yet been formed.

When removing sequestra or operating on a bony cavity, if a divided nerve is found the correct course is certainly to suture it, for very often it can be isolated sufficiently from the seat of suppuration; but this will be only an accessory to the main operation, that is to say, an exploration of the nerve would not have been undertaken if it had not been necessary to operate upon the fracture. This applies also to early operations on suppurating compound fractures.

The diagnosis between anatomical division and compression by callus is in theory very easy. The paralysis is immediate, sudden, and complete in the former case; late, progressive, accompanied by neuralgic pains, often with retention, at least partial, of some forms of sensibility, in the latter.

In the case of a patient who soon after being wounded has come under the care of an observant surgeon in a hospital where there has been sufficient time and opportunity for a complete and thorough examination, this differentiation becomes subsequently a simple matter. But often at the base we receive wounded after several weeks or months, bearing labels on which the information is insufficient. This is inevitable on the evacuation labels from the field-dressing stations. In action there is no time to devote to detailed observations (which are, moreover, of little use), much less to write them on the label. It could, I believe, be avoided in the notes of a regular hospital. But I have had to regret, even from these, the frequent absence of any accurate

notes. We are, then, often reduced to accepting the word of the patient, who has not always had the presence of mind to notice whether, at the time of the accident, a drop wrist or foot complicated the general uselessness of the limb, and once splints have been applied, has been no longer in a position to take notice of these points.

### 3. False Joints and Loss of Bony Substance

#### (1) Varieties of False Joints

Before studying the treatment of false joints, it is necessary to distinguish with care the varieties of delay in union.

The average time necessary for the consolidation of a simple fracture in good position in a young and healthy adult varies, according to the size of the bone, from one month in the case of a bone of the forearm to two months in the case of the femur. This period is lengthened (1) when reduction has been imperfect and the periosteum almost alone contributes to the formation of the permanent callus, (2) when the fracture is comminuted. It is an especially long period in cases of compound suppurating comminuted fractures, and in war surgery we have often to count on a fracture of the femur with or without a sinus taking from four to five months to become firm. A period longer than this constitutes a definite delay in union.

In theory, the difference between delay in union and a false joint is clear. Whatever time has elapsed, delay in union is characterised by persistence of the osteogenetic process ; a false joint by the final arrest of this process between the two fragments, each of which has undergone separate cicatrisation. In prac-

tice, the diagnosis between the two conditions is not always easy. The time that has elapsed, as I have just said, is not the criterion ; a simple fracture with an interposition of muscle becomes, so to speak, immediately an example of a false joint. On the other hand, certain fractures ultimately unite without any special surgical treatment at the end of a year or an even longer period. This remark applies especially to cases where irritation of the seat of fracture is kept up, suppuration having ceased, by the existence of a foreign body in the bone, whether it be a projectile, wire, a metal suture peg, or plate of surgical origin. One must judge of the question by radiography.

When the fractured bone remains flexible, if there is still a persistent sinus we should always admit in principle that it is a case of delayed union, and, after radiographic verification, extract the sequestra and excavate the diseased area. Very numerous are the cases in which, after several months of suppuration, clearing out the infected area of the bone, specially if there have been sequestra, leads to a rapid return of the process of ossification, which previously had come to an almost complete standstill. In operating for chronic osteomyelitis I have several times noticed that in the middle of the sub-periosteal hyperostosis the fragments of the diaphysis were united only by dense fibrous tissue, which later has undergone ossification.

Palpation of the site of fracture supplemented by radiographic examination enables us to form a fairly correct clinical conclusion.

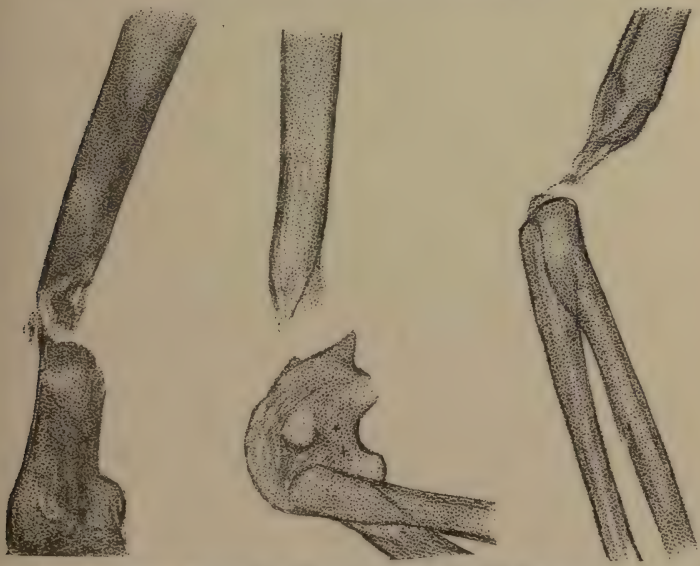
The principal characteristics of a real false joint are considerable abnormal flexibility, absence of pain on movement and pressure, and absence of tension

and œdema in the soft parts that are more or less adherent to the seat of fracture. If the bone ends are still enlarged and the soft parts infiltrated with œdema, if the bones are only a short distance apart and the amount of abnormal mobility slight, if movement causes pain and even light pressure is painful, then one may safely conclude that there is merely delay in union, in which there is no indication for a hasty operation.

In these cases radiography gives useful information, but one must be able to appreciate the exact significance of the various details. In the first place, it should be remembered that callus, especially intermediate callus, often casts no shadow on a X-ray plate for a considerable time, even though clinically the union of the bone seems complete (see fig. 1); again, it is often impossible to diagnose by examination of the negative cases in which the callus is still but poorly ossified; and when on manual examination we no longer find abnormal flexibility or tenderness, that does not mean that in the lower limb we may not be surprised by late angulation from bending of the callus under the body weight. The common fracture of Dupuytren long ago taught us the necessity of forbidding early weight-bearing when we suspect but slow ossification of callus.

When all suppuration has ceased and abnormal mobility still remains, radiography permits us to establish one of two points: the presence of a considerable bony loss, the end of the fragments being far apart, or else the presence around the seat of fracture of a greyish shadow with indefinite edges, a sign of very slow calcification of callus. In this latter case the value of successive radiographs at

monthly intervals in order to follow by the increasing opacity of the shadow the progress of ossification will at once be obvious; even where there is considerable loss of substance of the shaft, regeneration of bone from the sheath of surrounding periosteum



FIGS. 11–13.—Three examples of pseudarthrosis of the humerus; occurring in the middle of the shaft (fig. 11), in the lower part of the shaft with ankylosis of the elbow joint (fig. 12), the articular variety (fig. 13). In the last probably also the olecranon of the ulna has been resected. All three resulted in flail limbs, and in all were present sinuses which soon healed after the removal of small sequestra (fig. 11), or after excavation of a focus of caries (fig. 13).

is not at all exceptional if one only has the patience to wait for it.

In the typical plate of a true false joint the shadow of the fragments should appear opaque and of a regular or irregular shape, but with very clearly marked definite

margins like that of the bone of a completely healed amputation stump.

In war surgery the usual cause of a false joint in the shaft of a bone is this loss of too great an extent of bony substance, the result depending on whether there exists but one bone in the limb segment (arm and thigh) or two bones (forearm and leg). In the former case, elevation of the lower fragment often allows consolidation to take place at the expense of considerable shortening. In my experience, pseudarthrosis in the shaft of the femur is rare; in the humerus, it is rather more common.

Where there are two companion bones in the limb segment, if one has escaped fracture, or if fractured has united without or with but little shortening, it places a very definite obstacle in the way of approximation and union of the two fractured ends of the second bone. This condition of affairs occurs sometimes in the leg, more often in the forearm. Pseudarthrosis occurring simultaneously in both of the bones of these segments is very rare.

A special form, "articular" false joint, occurs when the loss of substance involves an epiphysis in the neighbourhood of a joint as well as the neighbouring part of the shaft, and when the wound has healed without ankylosis of the joint, which becomes flail. I have not seen examples of it in the ankle and knee joints, probably because fractures which would lead to this result have been such as to necessitate immediate or secondary amputation. This form of false joint, however, sometimes follows a resection of the hip, which has succeeded in saving the life of the wounded man, but which has resulted in a limb of but moderate utility, although infinitely superior to

an artificial limb fitted to the pelvis after a disarticulation at the hip joint.

The usual position, however, for an articular false joint is in the upper limb, sometimes at the wrist joint from loss of the lower end of the radius, more often at the elbow and shoulder from loss of the corresponding epiphyses of the humerus.

The regular pathological type of false joint is that of fibrous union, the tapering bone ends being joined together by bands of fibrous tissue; close fibrous union, rather rare, when the bone surfaces remain in contact, and when, if there is no interposed muscle, a late, slow ossification may for a long time be hoped for; and flail fibrous union, more common when a considerable length of fibrous tissue replaces the lost bone. I have not seen cases of real "false joint," that exceptional form with fibrous ligaments and synovial lining.

### (2) Treatment of Non-union

It is necessary carefully to distinguish between the treatment of mere delayed union and that of true pseudarthrosis.

#### A. *Delayed Union*

I have already explained the rôle played in this by sequestra and foreign bodies, and the necessity for their removal.

In cases where neither of these two causes of delayed union exists, where suppuration has ceased, and there is no foreign body, and where on the removal of splints after the usual period abnormal mobility is found to exist, the difficult problem arises whether to persist in immobilisation or to leave the limb more or less unrestricted in its movements.

There are of course cases of delayed union—often wrongly described as false joints—in which, after a delay of some months, new bone formation has been stimulated by some purposive form of irritation of the seat of fracture—*e.g.* the old methods of treatment, forcible rubbing together of the fractured end, injection of mild chemical irritants, and acupuncture.

These various procedures are probably no more efficacious than permitting slight movement at the seat of fracture, the limb being either left free of all apparatus and lightly massaged, or else put up so that the movements of the neighbouring joints which are left unrestrained by apparatus cause a certain restricted amount of movement at the seat of fracture itself. A little movement is allowed, but only a little.

As a general rule, this latter procedure seems to be preferable either to absolute immobilisation or to leaving the limb quite free. We should try it for successive periods of three to four weeks, noting at each change of apparatus whether the mobility appears less, and whether radiographs show an increase of ossification in the callus.

For this purpose the extension apparatus of Delbet for the humerus and femur, and his plaster splints, which allow the patient full use of the limb in fractures of the tibia and fibula, are most excellent. I am accustomed to apply these as soon as the pathological state of the parts allows of it, and to continue them as long as one is certain that a false joint does not exist.

If the delay in union is prolonged, particularly in the lower limb, and above all in the leg, it is easy to substitute for these heavy splints orthopædic appa-

ratus similar to that prescribed for inoperable false joints, or for those in which operation has failed. This method of treatment avoids two very common practices which are to be condemned, viz. in the case of the upper limb, keeping the arm in a sling; in the case of the lower, giving the patient a pair of crutches.

Patient and careful observation is necessary before finally concluding that the process of consolidation has definitely come to an end.

### B. *False Joints*

The means of treatment at our disposal are :—

1. An open operation with the object of obtaining bony union.

2. The wearing of an orthopædic apparatus.

The principles of the orthopædic apparatus vary with the different segments of the two limbs; those of surgical operations are, however, general and constant.

(a) *If the fragments are in contact without loss of substance*, the old method of freshening the bone ends should first be tried. The seat of fracture is opened up, the periosteum preserved with the greatest care, intermediate fibrous tissue excised, and the ends of the bone freshened either with the curette or the saw, with the object of obtaining close contact between healthy, well-vascularised bony surfaces. By doing this there necessarily results a certain amount of shortening, usually of no importance in the case of the humerus, and even of the femur—where, however, pseudarthrosis rarely occurs—but incompatible with accurate coaptation of the cut surfaces in those segments of the limbs where there are two bones and

the other is sound. If the separation of the surfaces is not great, this difficulty may be overcome by resecting a short segment of the normal bone; if the separation is considerable, we must have recourse to a bone graft.



Fig. 14.—Osteitis kept up by an attempt at wiring for non-union.

After freshening the ends most surgeons assure the maintenance of the freshened surface in good and close apposition either by suture of the bones or by one of the methods by which this has been replaced and simplified in recent years (metal plates or staples), or else by an intramedullary peg of ivory.

I believe that there is a tendency to abuse the insertion of these foreign bodies in bone. Even when the seat of the fracture has throughout been closed and aseptic they irritate the bone, cause rarefaction, and provoke the formation of callus, which is exuberant but at the same time insecure. Secondary sinuses are far from being exceptional. Moreover, it is often possible without these to maintain good position by means of well-fitting external splints; but when this latter course is impossible, it is, in my opinion, better deliberately to remove the foreign body as soon as the callus has commenced ossification. Consequently I prefer fixation with wire, or, better still, with a staple, to the use of intramedullary pegs (fig. 14).

(b) *If there is such loss of bone* (either originally or

as a result of removal by operation) as is incompatible with coaptation of the fragments, we must have recourse to bone grafting.

Sometimes it is possible to insert into the gap a bony fragment with an adherent pedicle taken either from the bone itself or from a neighbouring bone. I shall describe this in connection with losses of substance of the tibia repaired from the fibula (see p. 35).

Most often a separate fragment is taken from a distance :—

Either from the patient himself, *autoplastic graft* ;

From an animal of the same species, *homoplastic graft* ;

From an animal of a different species, *heteroplastic graft.*

It is generally recognised that success is more likely if the graft retains its own periosteal layer, but this is not indispensable.

In the case of a pseudarthrosis a graft of large size must be used, and most often an attempt is made to introduce its two ends into the medullary cavity of the existing fragments.

From the study of experimental grafts in animals, and from their use in man in an aseptic field of operation, it has been found necessary to discriminate between two things, the " taking " of the graft and its ultimate fate.

I shall not consider cases where suppuration occurs and the graft comes away ; the first condition of success is primary union of the operation wound. Further, it must be understood that antiseptics must not be used ; they adversely affect the vitality of the cells.

In an aseptic case the graft usually " takes," even

when it has been heteroplastic. In man, radiography has shown the bony fragment surrounded by callus ; in animals, its survival and vascularisation have been established by post-mortem examination. The frequency of this immediate success should not, however, be exaggerated. More often than could be wished it is only partial : the fragment survives, but remains free at one end, sometimes even at both ends, and consequently consolidation is not obtained.

Even in cases that for weeks keep up a promise of ultimate success, one is liable finally to fail owing to a late but progressive absorption of the graft.

The present consensus of opinion is that even with an autoplastic graft this absorption is constant, or almost constant. The graft plays its part merely by exciting and directing an osteogenesis by substitution. This is a source of discussion of great scientific interest, but of no very great practical importance. If secondary ossification of the graft has occurred, it matters little whether the ultimate callus is formed by the transplanted bone itself or by new bone which has gradually replaced it, so long as in the end the continuity of the bony lever is re-established.

But if absorption takes place quickly substitution has not time to occur, and the final result is failure. Occurring in all three varieties of grafts, this excessively rapid absorption occurs in an increasing order of frequency with autoplastic, homoplastic, and heteroplastic grafts. Further, it may be said that the heteroplastic graft, the taking of which is more dependant on chance, and the absorption of which is more frequent, has not up to the present progressed beyond the experimental stage, despite a few fortunate successes, of which there are even some in classical

surgery. This is a pity, because they constitute the most convenient method of obtaining at any time a massive graft.

An opportunity for the use of homoplastic grafts but rarely presents itself, and even when it does there is always the fear, despite all clinical and laboratory precautions, of inoculating the recipient of the graft with tuberculosis or syphilis.

Grafting by the autoplastic method alone is therefore carried out with any frequence, and the transplanted pieces are almost always taken either from the fibula (the whole middle third of the shaft of which can be resected without leaving functional disability), or from the tibia, whence a sufficiently long piece can be taken without difficulty from the crest.

*Indications.*—What I have said as to the absolute necessity for primary union after bone grafting, and its almost equal necessity after simple freshening operations with or without bone fixation, indicates that in war surgery the frequent recrudescence after open operations of infection, over which we have no control, forms a great stumbling-block in the way of success. It is advisable, therefore, to wait a very considerable time before operating; all vascularity should have disappeared from the scar, and the neighbouring tissues should be quite supple, and even then there is no absolute assurance of success.

Even if the wound does not suppurate, failure to secure union is not at all rare.

In spite, then, of the incontestable progress of the last thirty years, the treatment of " false joints " by open operation remains uncertain. This is, however, no reason for refusing to consider operation as formally indicated if the functional disability is

serious—as is usually the case—even if in case of failure one has to fall back on an orthopædic apparatus: nothing is risked, and the gain may be considerable.



Fig. 15.

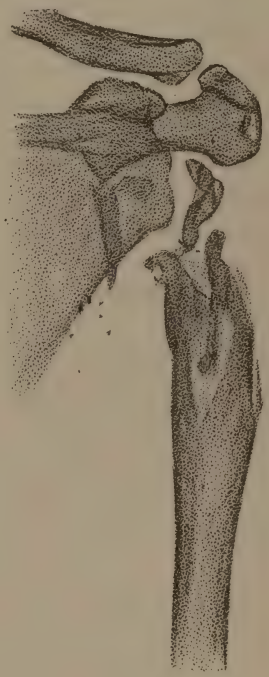


Fig. 16.

I will now enumerate bone by bone the chief functional troubles which constitute indications for treatment.

In the case of the humerus, whether it be in the shaft itself, at the shoulder, or at the elbow, the type is that of a loose pseudarthrosis. This does not mean that the limb is useless. In extension the arm

hangs beside the body limp and swinging like a pendulum. But if the muscles are good—particularly the deltoid for the shoulder and the long muscles for the arm and elbow—the effect of their contraction



Fig. 17.

Figs. 15–17.—Flail pseudarthrosis of the humerus; involving the shaft (fig. 15) and the upper articular extremity (figs. 16 and 17). In cases 15 and 16 there are present sequestra whose removal was followed by rapid healing. In case 17 a sinus was due to disease in the fractured scapula.

is to raise the lower fragment, and then by supporting it against the upper, with, sometimes, a remarkable security, to allow of fairly vigorous action of the wrist and hand, the elbow remaining flexed. In the case of a false joint in the shaft the lower fragment is held by the triceps so as to make with the upper

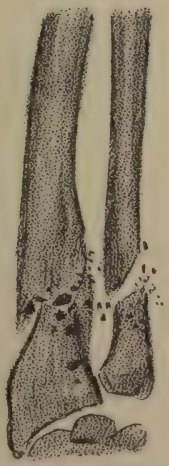
fragment an obtuse angle open backwards; in this position the biceps can quite adequately flex the elbow and hold it flexed. By the use of a circular armlet which leaves the elbow free, the functional utility of such a limb can be considerably increased. In order not to constrict the limb and interfere with muscular action it is best for this armlet to have a proximal attachment to a shoulder piece which is fastened round the trunk.

In pseudarthrosis of the humerus cure by open operation is most difficult to effect. When the head of the humerus has been resected with the upper part of the shaft a vigorous deltoid can raise the lower fragment directly and keep it in contact with the glenoid cavity. But in all the cases of this sort that I have seen in war surgery there has been complete atrophy of the deltoid, and if ankylosis had been effected the functional result would have been better. Hence in cases of this sort original resection of the upper end of the humerus should be performed only when, in order to save life, the choice lies between this resection and disarticulation at the shoulder joint. Conservative measures which would result in ankylosis should be abandoned only after a full realisation of these facts of the case.

In the case of the elbow adequate voluntary movement at the site of the false joint is not rare; indeed some surgeons consider the functional result better than that of ankylosis of the elbow in good position—the muscles of the forearm and hand being equally good—therefore they prefer to treat by free and early resection fractures of the lower end of the humerus, of the upper ends of the forearm bones, or of the ends of all three bones. I speak here of immediate or early

secondary and not of late orthopædic resection, which, being sub-periosteal, allows of the reconstitution and remodelling of a firmly ankylosed joint. When the fixation by the long muscles is insufficient—when the muscles are poor, or else the loss of bone too great—





FIGS. 18 and 19.—Pseudarthrosis in the lower half of the radius (fig. 18) and of the ulna (fig. 19), in the latter bone with but little loss of substance.

the elbow should be fixed in an apparatus fitted with a ratchet, which encircles the arm and forearm, and is suspended from the shoulder in the manner already described to avoid compression of the muscles.

In connection with these fractured shoulders and elbows I draw attention to the attempts that have been made to insert under the soft parts artificial joints of ivory fixed to the neighbouring bones. I

mention these solely to show that I am not ignorant of them.



Fig. 20.—Pseudarthrosis in the middle of the shaft of the radius, with considerable loss of substance. Cavity containing sequestra in the ulna.



Fig. 21.—Loss of substance of the fibula without the occurrence of displacement of the foot (the external malleolus has escaped; ankylosis of the ankle joint).

Pseudarthrosis, even if fairly firm, of the two bones of the forearm results in a grave disability, which is sometimes complete. That of the radius alone is

almost as disabling because of the loss or limitation of the movements of pronation and supination, and because of weakness of the fingers, the hand being flexed in a bad position; when the lower radial epiphysis has disappeared the hand deviates to the outer side, supination is impossible, and weakness of grip of the fingers is very marked. Pseudarthrosis of the ulna is much less disabling, especially when it occurs in the lower half. It may even be a good thing, especially when the radius is badly united, the lower fragments being pronated, causing sometimes less complete limitation of supination.

The forearm is the region where fibrosis and destruction of muscles and tendons and nerve lesions most frequently complicate non-union of bone and increase considerably the functional disability of hand and fingers.

If an operation by freshening the ends with shortening of the second bone (if it be intact) or by bone grafting fails, a fair result is obtained by the use of a leather armlet in pseudarthrosis of the shaft. Neither operation nor orthopædic apparatus is, however, of much use in loss of the lower extremity of the radius.

In the *femur* I have as yet seen no case of non-union of the shaft among the many wounded that I have examined. I believe that simple freshening without grafting would be sufficient. In case of failure, one would apply an apparatus transmitting the weight from the tuber ischii to the foot, like the caliper used in the convalescent stage of hip disease. The same also is useful in the case of a flail hip joint after resection; after this operation, however, ankylosis is much more commonly met with.

I have seen no flail knee joint; cases where loss

of bony substance is sufficiently extensive to lead to this result are usually treated by early resection or amputation.

In the leg, pseudarthrosis without being frequent is not rare. The most striking characteristic is the lack of stability in the limb in the standing position, hence there is a very considerable difference between pseudarthrosis of the tibia and of the fibula. A loss of substance of the fibula—even when considerable—is almost always without functional importance, provided that the external malleolus and its attachments are preserved; but if this is lost, deviation of the foot into valgus as soon as it touches the ground constitutes a very serious disability. The operative indication is then to arthrodese the ankle joint at a right angle, as is done for congenital absence of the fibula. I have seen a case of considerable loss of substance, but with preservation of the malleolus and stiffness of the ankle joint—which had been kept in a good position by the surgeon—walk very well and firmly, the sole of the foot flat on the ground (fig. 21).

Pseudarthrosis of the tibia without loss of substance, or with but slight loss—2–3 cm.—may often be treated successfully by freshening combined with shortening of the fibula, or else by a bone grafting, by freshening of the two bones if the fibula also has not united. In cases of failure a walking apparatus, with support from the tuberosities of the tibia attached to the thigh, like but very much lighter than an apparatus for amputation of the leg, almost always gives a fair amount of functional use.

The most difficult cases are those in which there is such excessive loss of substance of the tibia as renders impossible any attempt to procure contact between

the two ends even after resection of the fibula. By means of a bone graft it is also impossible to reconstruct the tibia sufficiently in length and in thickness. In such conditions, sometimes callus forms spontaneously in a favourable manner, one or both ends of the tibia becoming united to the fibula, which has itself been broken but has joined, so that the fibula itself transmits the body weight; this bone is reinforced by callus—it seems to develop later little by little, and adapt itself to its new function, and the final result is often satisfactory. It is possible in some cases to imitate this natural process by surgical methods (figs. 22 to 25). Sometimes the shaft of the fibula has been implanted into the upper end of the tibia; sometimes, on the contrary, into the lower end of the tibia; sometimes, by two operations, both ends of the fibula have been implanted in turn, so as to substitute one entire shaft for the other (figs. 23 and 24). In this last case, although the absence of the middle part of the shaft of the fibula usually results in no disability, it is well to guard against the occurrence of a valgus deformity of the foot by creating a synostosis between the lower ends of the tibia and fibula.

It is more in accordance with the normal mechanics of the leg, however, if, following Curtillet, the transplant is taken not from the whole of the fibula but only from the anterior half of its thickness. This osteoplastic strip, nourished by an internal pedicle formed of musculo-periosteal insertions carefully left untouched, is passed through an opening made into the antero-external muscles of the leg, and is placed between the two ends of the tibia, freshened and shaped like a fork (fig. 25).

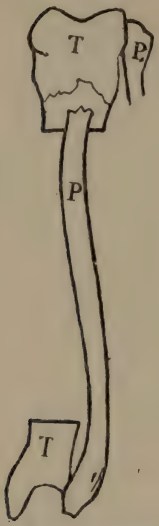



FIG. 22.—Simple transplantation of the upper end of the fibula into the upper fragment of the tibia.

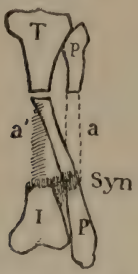



FIG. 23.—At the time of the operation.

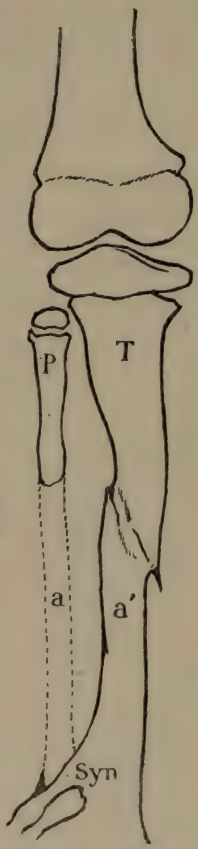



FIG. 24.—The final result.

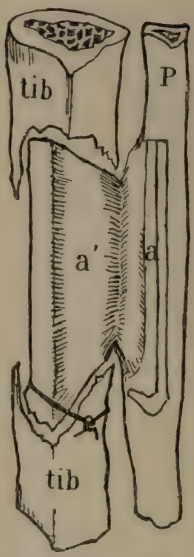



FIG. 25.—The operation of Curtillet—a fibular flap *a* is transplanted into *a'*, the gap in the tibia due to loss of bone.

FIGS. 23 and 24.—After grafting of the upper end of the fibula into the upper end of the tibia, and after the performance of arthrodesis of the inferior tibio-fibula articulation, the fibular shaft *a* replaces the tibial shaft *a'*.

After these various operations it has been frequently proved that the graft, studied by a series of radiographic plates, has rapidly grown and become an excellent tibial shaft.

Thanks to these methods, operative and instrumental, we may say that amputation is no longer indicated at the present time so far as the upper limb is concerned, and hardly ever in the case of the lower limb. It is possible, however, that in certain cases of flail pseudarthrosis of the leg this mutilation may be advisable—as in certain congenital false joints—if we consider that the apparatus will be more simple, and the support more secure with one of the excellent artificial limbs that can be made to-day for amputations in the lower part of the leg.

## CHAPTER II

# CHRONIC TRAUMATIC OSTEOMYELITIS

*(as seen in amputation stumps and infected fractures)*

### 1. General Consideration of Osteomyelitis

In order to understand the pathology and treatment of bony sinuses following gunshot fractures and amputations it is first necessary to grasp certain general principles of the pathology of bone inflammation.

Inflammation of bone has, as the result of conditions that it is not always easy to define clinically, two possible but opposite results, the production of new bone, and rarefaction. Proliferative or condensing osteitis (osteosclerosis) and rarefying osteitis (osteoporosis) must be studied respectively in the compact tissue of shafts of long bones (and in the compact layers of flat bones) and in the cancellous tissue of short bones and epiphyses.

Bone tissue—whether compact or cancellous—is made up of two elements, one soft, vascular and continuous, the bone-marrow, whose physiological function is to produce and then to nourish the other, which is hard and calcified and forms the rigid framework of the skeleton. It may be said gener-

ally that an inflammation of moderate intensity—for example, aseptic irritation—results in an increase in the bone-producing power of the marrow, giving rise to osteosclerosis; whilst a more severe pyogenic infection diminishes this power of the marrow, which proliferates as fleshy granulations and erodes by a process of osteoporosis the neighbouring hard parts of the bone.

In the long bones there are three parts to be considered: the periosteum, the cylinder of compact bone, and the central medullary canal.

Under the periosteum, a fibrous and practically inert membrane, lies an active layer (the osteogenetic layer of Ollier), which plays a great part in the growth in thickness of the bone. The osteogenetic activity of this layer is much the greatest in young subjects.

The compact cylinder of bone is made up of concentric layers, and is tunnelled from end to end by the straight Haversian canals in which, surrounded by cells of medullary tissue, lie the capillaries which nourish the bone. These canals anastomose among themselves by transverse branches, of which the most external open under the periosteum. Hence a continuity of blood-vessels and of marrow tissue exists between the sub-periosteal layer and the Haversian canal system. The most internal of these branches open into the medullary canal.

Now this medullary canal is really only a huge Haversian canal. It contains the bone marrow in the common sense of the term. This central marrow has normally little or no osteogenetic power. It acquires such power in certain pathological conditions, but only rarely and to a slight extent.

Let us see now how these various parts behave during osteomyelitis of the shaft of a bone.

If the periosteum has not been destroyed mechanically or by infection, its osteogenetic layer usually reacts by an exaggerated osteogenesis, hence the sub-periosteal hyperostosis which ensheaths the bone and thickens it. This hyperostosis becomes thicker as it is traced towards the actual seat of the osteitis, so that where the lesion occurs in the middle of a shaft the mass is fusiform, where at the junction of the shaft and epiphysis it tapers or is club-shaped. At the edges of the infected area, if the infection be intense, this hyperostosis is spongy in character, rarefied by the process of inflammation, but for the most part it tends to be hard like ivory.

The central marrow may exceptionally give rise to new bone. Usually it proliferates, increases in vascularity and volume at the same time as, by an enlargement of the medullary canal, the compact tissue of the diaphysis, which contains it, becomes thinned.

Caught, as it were, between the infection of the periosteum, stripped up by the suppuration and the turgid marrow which strangles the vessels in the rigid walled canals (central canal or Haversian canals), the bony cylinder of the shaft undergoes necrosis at the site of infection. This necrosis affects a very variable extent of the length and circumference of the shaft, and extends to a greater or less depth ; beyond it rarefaction occurs ; further off still, condensation.

Necrosis and rarefaction are two associated processes.

In compact tissue necrosis occurs *en masse* ; the

dead part is dense, white, and smooth; it sounds clear and dry on percussion with a probe. At first it is in actual continuity with the surrounding living tissues, just as the slough caused by a burn of the third degree is at first continuous with the sound skin. But in both cases, if there be infection, the connective tissue proliferates, becomes congested, and suppurates at the junction of the living and dead parts. At the junction of the necrosed part the Haversian canals become larger, the bone tissue becomes rarefied and then disappears, eaten away by granulation tissue. A red line of demarcation appears and gradually deepens around the white necrosed bone; thus in time the dead piece of bone is set free on all sides and to its full depth. Necrosis has thus been followed by the production of a sequestrum—free, white, and hard, but characterised on the faces and edges, that originally were adherent to the rest of the bone, by fine serrations—comparable to those hollowed out by the sea in a rocky coast.

The sequestrum would now be ready to work its way out—just as the slough of a burn falls off—if sub-periosteal ossification had not progressed simultaneously with the process of its liberation; so that it finds itself enclosed, ensheathed in a sequestral cavity formed laterally by the new periosteal bone, and above and below by the remaining parts of the former bone. This cavity, whose walls are in places hard, in others soft, is lined by soft, fleshy granulations. It contains, besides sequestra, pus, and it communicates with the outside by perforations of various sizes, in which the sinuses of the soft parts end.

In the region of the spongy bone of the epiphysis

sub-periosteal bone-formation is almost or quite absent. Here rarefaction is predominant, with proliferation of the marrow, which is sometimes purplish-red, and sometimes yellow and fatty. The bone trabeculæ for the most part disappear by progressive absorption, and in their place are hollowed out cavities filled with granulations or collections of pus. Sometimes, but rarely, a central islet dies *en masse* and constitutes a porous and light sequestrum. The process is the same in thick, short bones, especially in the tarsus. Usually the infection and rarefaction spreads to the whole spongy mass of bone. The name *caries* is given to this form of osteitis with softening of the tissue, through which the probe and curette pass as through butter. I do not think that this name, which is purely symptomatic, should be reserved for tuberculous osteitis alone.

Caries may also eat away more or less completely the compact tissue of a diaphysis.

### 2. Amputation Stumps that require further Operation

These general facts being known, the most simple application of them to traumatic osteomyelitis may first be studied in the bony lesions of a suppurating amputation stump.

We can easily follow the changes in the cut end of the bone with the naked eye and also radiographically.

When the infection is but moderate the bone end appears white around the red and slightly projecting central marrow; then a red stippling marks in it the enlargement of the Haversian canals and the proliferation of their marrow. Very soon a carpet

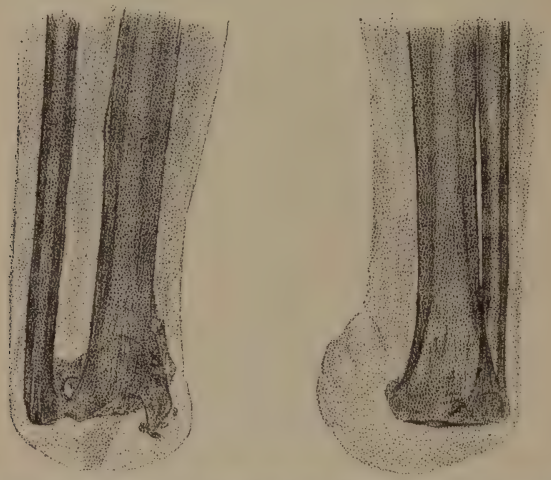
of granulations covers the bone uniformly, practically no necrosis having occurred—except for such as crumbles and is thrown off almost invisibly from the bone as a sort of bone dust and is carried away in the pus. By ossification of the medullary granu-



FIG. 26.—Amputation of thigh ; a good clean division of the bone which is well covered by soft parts.

lations a layer of bone is formed which obliterates the Haversian and central canals. This occlusion of the medullary canal is often one or two centimetres deep, and above it the cylindrical medullary canal ends by tapering to a point (fig. 29). The end of the bone thus becomes much more dense ; further up the cylindrical shaft is normal, no sub-periosteal proliferation having taken place around it. Hence

radiography shows a bone with sharply marked edges, the cut surface smooth and free, such as that represented in fig. 26. If the soft parts around the bone are ample enough, healing occurs without complications; a scar forms which at first is adherent, but later becomes supple and movable, and ends by



Figs. 27 and 28.—Amputation of the leg (antero-posterior and lateral views), with the formation of hard new sub-periosteal bone, causing, however, no inconvenience; bone-end quite well covered.

being practically as good as that of a stump that has not suppurated.

In certain other cases, where the inflammation has been rather more severe, the end of the bone becomes surrounded by new bone of sub-periosteal origin. In such cases the cut end of the bone is enlarged into a club-shaped mass, or presents terminal excentric projections of bone, which in a radiograph appear as a dark, dense shadow, spur-like in shape,

of varying length, and usually concave on their proximal surface (figs. 27 and 28). On examination this hypertrophy may be felt, but the bone is found to be well covered by soft parts, and not at all tender on pressure, the osteosclerosis forming in reality a good solid bony scar.

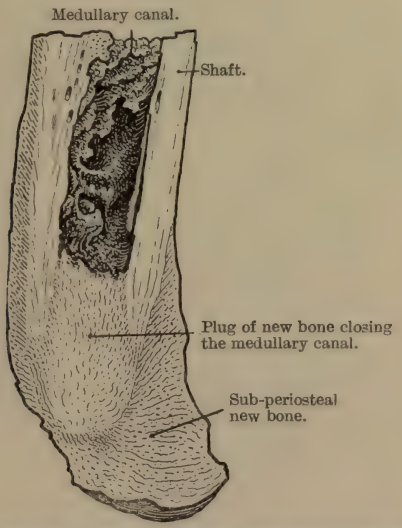



FIG. 29.—Bone-end quite soundly healed; re-amputation was necessary on account of shortness of the soft parts. During the performance of this operation one could see the original bone closed by a mass of new bone in the medullary cavity and surrounded by new sub-periosteal bone.

If the flaps of soft parts are, however, too short a thin, unsound cicatrix adheres to the end of the bone, and is often subject to recurring ulceration. If they are very short, the scar adheres like a collar around the granulating end of the bone, on to which the epithelium cannot extend—a chronic terminal

ulcer results, even though there be no underlying osteitis.

The phenomena are very different when in cases of severe infection necrosis and caries occur with

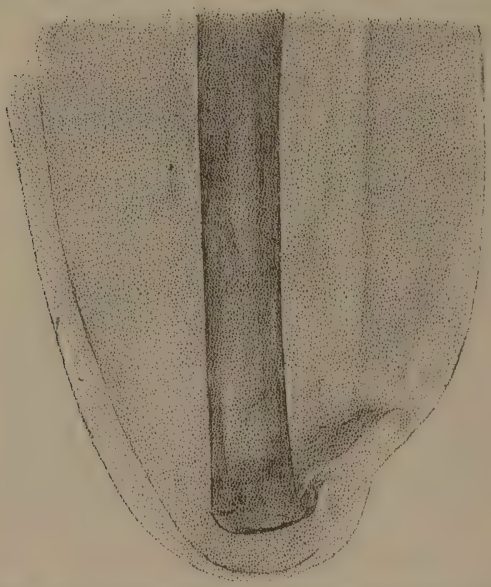


Fig. 30.—A projecting terminal spur of bone well covered.

exuberant over-production of sub-periosteal bone, which itself becomes the seat of caries.

Then a mass of purple granulations projects from the medullary canal and extends in a mushroom-like excrescence over the cut surface of the bone, which remains white until exposure to the air blackens it. The bone end undergoes necrosis for a variable length—rarely more than 3–4 centimetres—a part, or more often the whole, of its circumference being

involved. This in the end constitutes a sequestrum which usually, in from six weeks to two months, becomes free in the form of a ring, the lower edge of which—owing to the saw-cut—remains smooth and plane, whilst the upper, isolated by rarefying



FIG. 31.—A terminal spur poorly covered; terminal ulceration of the soft parts which are too short, some slight osteitis.

osteitis, is irregular and jagged, with sometimes very sharp points projecting up along the sides of the remaining part of the shaft. This upper edge is more or less overlapped by the periosteal new bone, which may even descend around and in part enclose the lower border of the sequestrum (figs. 33 to 38).

In less severe cases the new bone formed and the old shaft undergo osteosclerosis above and

around the sequestrum, the spontaneous elimination of which (or surgical removal by curetting) is sufficient to lead to the healing of the sinus. After that the nature of the stump will depend, as I have just said, on the length of the covering soft parts.

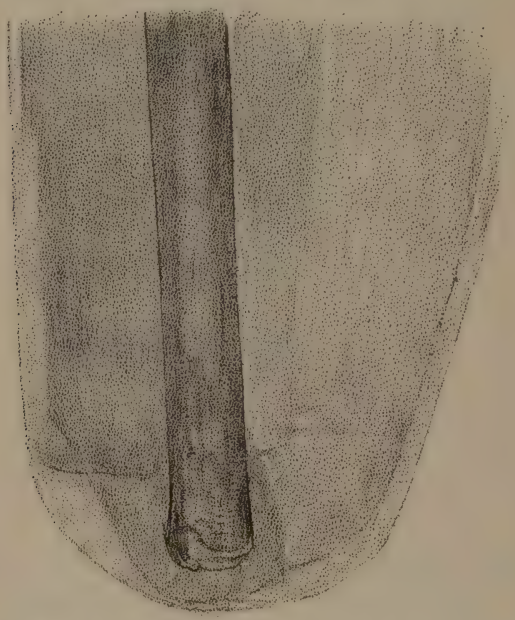


Fig. 32.—Slight amount of osteitis in a stump with a chronic sinus.

But often under these conditions the sub-periosteal bone is excessive, forming a cauliflower-like mass, which is rarefied and excavated by granulation tissue and by small suppurating cavities. In the original bone the central marrow becomes fatty, increased in amount, with a corresponding increase in diameter of the medullary cavity and thinning of the compact

cylinder of bone, which sometimes becomes reduced to a layer as thin as parchment. In extreme cases of this sort this shell of compact bone may become enlarged and distended as in a spina ventosa—a condition that may extend right up into a softened and carious epiphysis, even where the primary amputation has taken place through the middle of



Fig. 33.—A terminal ring-shaped sequestrum enclosed by sub-periosteal bone ; bone-end well covered, but sinuses present.

the shaft of the bone. Such a condition is not uncommon in the upper tibial epiphysis after amputation of the leg at the seat of election (figs. 39 and 40).

Radiographically the bone appears very much enlarged, the general outlines of its shadow being opaque, but with translucent streaks and patches. Below the end of the bone often appears an irregular shadow of very variable shape, of a uniform grey colour, with no sign of any trabecular structure.

This light shadow shading off into that of the surrounding soft parts (fig. 41) has no very well-defined

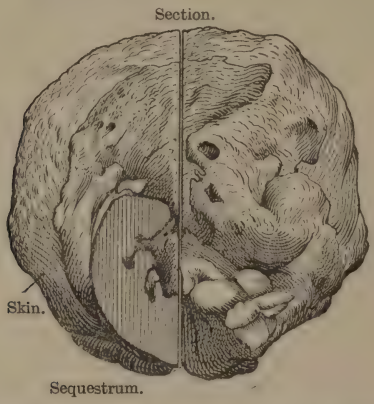



Fig. 34.—The sequestrum is seen presenting its plane surface of the original saw-cut.

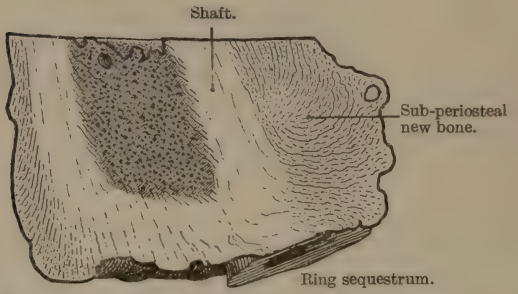



Fig. 35.—This shows the way in which the sequestrum may be surrounded by new bone. Some slight extent of osteitis present in the latter.

outline; it sometimes shows translucent patches, in which the presence of sequestra may be detected (figs. 42 and 43).

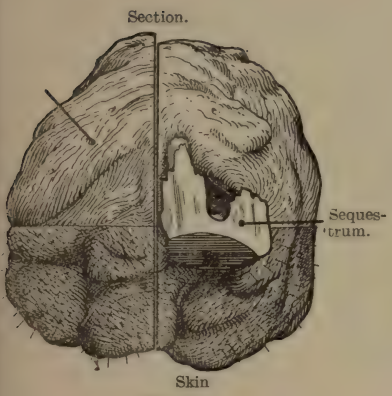



FIG. 36.



FIG. 37.

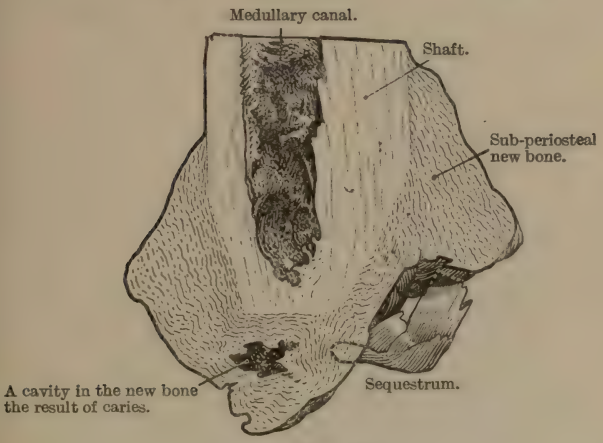
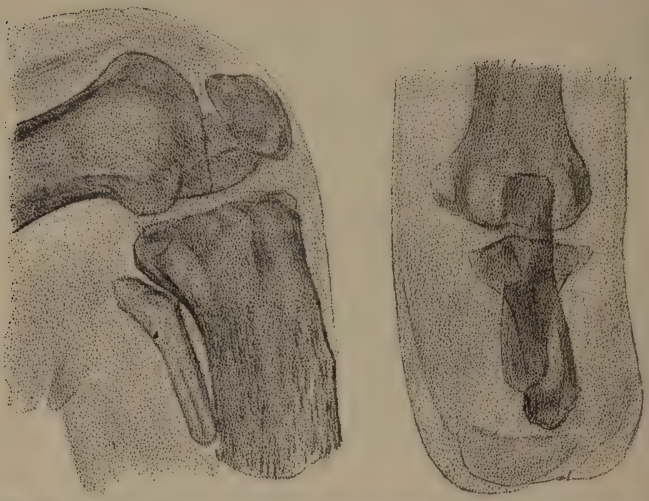



FIG. 38.

FIG. 36.—Radiographic appearance of a terminal ring-shaped sequestrum sticking out through the skin and enveloped by new subperiosteal bone (figs. 37 and 38). A slight amount of caries in the end of the bone.



FIGS. 39 and 40.—Rarefying osteitis involving the whole remaining portion of the tibia and of the radius. The bone is swollen and distended, with, however, no sub-periosteal proliferation.



FIG. 41.—Rarefying osteitis with sinus, formation of a large terminal cauliflower-like mass of new bone.

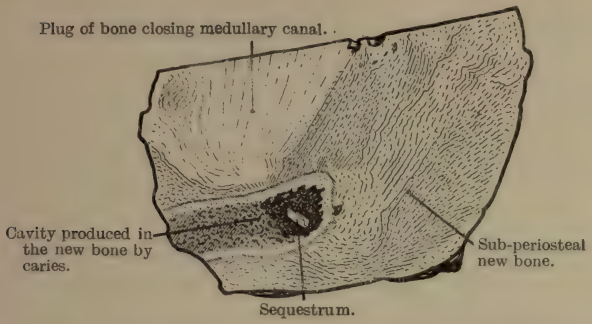



FIG. 42.—A small sequestrum of sub-periosteal bone producing an area of caries.

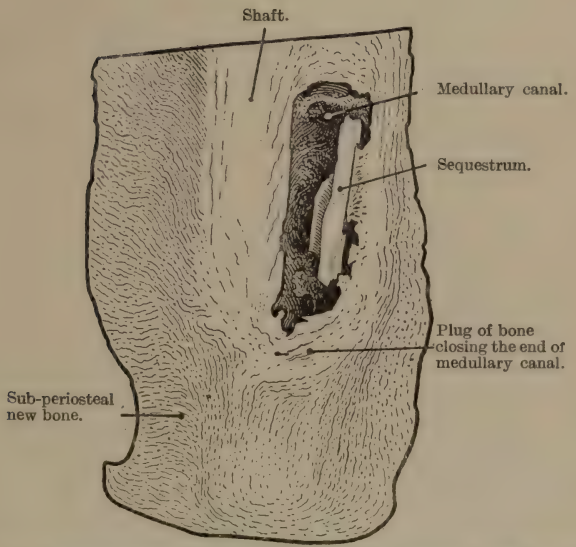



FIG. 43.—A sequestrum of compact bone, of the original shaft, lying proximal to what appears to be a soundly healed bone-end.

Such a stump is, as a whole, hard and bulky; its soft parts, often œdematous, are lacking in suppleness; below they are hard, often indurated, covered by skin in a state of chronic, even acute, inflammation. This skin, ending in a collar of fibrous tissue, becomes retracted upwards like a funnel towards the end of the bone, to which it is adherent, and connected by one or more sinuses of variable size. The bone, sensitive to pressure for a considerable distance upwards, is extremely tender at its extremity. The sinuses discharge pus, often thick, and very variable in amount. At times they almost or completely close; this leads to a reappearance of the inflammation, with redness, pain, swelling, and slight fever; an abscess forms, and the scar breaks down afresh. Or else in the seat of a former sinus there gradually forms a swelling, soft, dull red in colour, but without any marked signs of acute inflammation; in time this bursts, discharging a little turbid serum, and the sinus so formed recommences a longer or shorter period of discharge.

As long as the stump is suppurating it is of course impossible for the patient to wear an artificial limb. Even where the suppuration itself has definitely ceased, as long as the soft parts remain œdematous, adherent to bone that is itself enlarged and tender, the friction of an artificial limb will soon light up the infection afresh, and produce new abscesses and sinuses. This fact, of common knowledge to surgeons in time of peace, has often been forgotten by the neophytes in surgery that the war has produced; and I have often seen patients with amputated limbs who, fitted with an artificial limb far too soon, have had later to submit to further operations that

have so changed the shape of the stump that their former limb no longer fits sufficiently accurately. This happens especially in the case of the lower limb, where the stump must transmit body weight in the vertical plane, and where, consequently, accuracy of fit is of the greatest importance.

Such being the principal pathological and clinical varieties of infected and suppurating stumps, let us next consider what operations are necessary in order to bring about final healing, and so to prepare the stump for the reception of its artificial limb.

The simplest case is that in which the bone itself being soundly healed, the end of the stump still remains adherent, or is incompletely healed or liable to constant recurrence of ulceration, the soft parts being too short to cover and pad the bone end. This is the chief defect of circular amputations in which suppuration has occurred, or in which, although suppuration has not occurred, the soft parts have been cut too short or have been insufficiently undercut. This result is frequent even in the hands of the best surgeons, those who in the presence of an injury necessitating amputation have always been accustomed to amputate if possible through the actual seat of injury, the stump being well drained and retrimmed at a later date. But in such amputations surgeons have always in the past sought to preserve as much as possible of the soft parts which they know full well will be so very useful later when the time comes to retrim; but I raise my voice once more against the system of guillotine amputations—the soft parts being cut in the same plane as the bone—that seems to be so popular at present. The more one has been sparing of the soft parts below the level

of the bone section, the less of the bone will have to be resected later in order to adapt its length to theirs.

The treatment of these conical stumps consists in shortening the bone.

By one, or better by two lateral incisions the fibrous collar that surrounds the bone is cut up; thus are defined two flaps, each consisting of one-half of the circumference of the adherent soft parts. Some surgeons after having with the knife joined the ends of these incisions, advise deepening them right down to the bone so as to remove deliberately the periosteum from what is going to be the new end of the bone, this in the fear lest proliferation of this periosteum lead to an excess of new bone. I believe that they are wrong, and I am accustomed after having deepened the incision down to the bone, all round the adherent scar, to liberate the bone with the rugine to the height thought desirable.

This height should be calculated as for an ordinary amputation, so that the skin and muscle cover the bone end without tension; in these particular cases this necessitates in addition careful freeing of the skin by undercutting.

This skin is usually puckered into a funnel shape by the thick and dense sclerotic ring that has been cut by the freeing incisions and separated from the bone; it should be cut through completely up to where the knife, cutting on the flat between skin and deep fascia, reaches the normal loose subcutaneous tissue. Only then can the edge of the skin be doubled back. If one can so plan the incision that the scar which has been terminal becomes lateral and the end of the bone thus covered by a thick muscular flap, the result will be all the better.

In cutting the bone, the free end of which should be held with Farabœuf's forceps, it is often most convenient to use a Butcher's saw with the blade reversed, the teeth towards the frame, the bone to be cut thus occupying the space between blade and frame.

After this operation primary union should be attempted: one or two deep stitches put in the muscles, and the skin sutured. But I am sure in all such cases it is wise to provide adequate drainage, for although reinfection is less common than where the bone end itself has been infected, yet it is not unknown. It is obvious that the danger of infection could be avoided by reamputation through healthy tissues higher up the limb, but in most cases this means too great a sacrifice of length of bone.

If there be present necrosis and caries of the bone end it is best to await the loosening of the sequestra. Then the operation is performed in exactly the same way, the bone being divided well above the terminal mass of diseased new bone in which the sinuses end. In many cases, however, this high division of the bone above the gross limits of disease would result in too great a sacrifice of length of the stump; especially is this so in cases in which, the epiphysis above being involved, it would necessitate the sacrifice of the joint above or else so near an approach to it as to render it practically useless. The chief indication in such cases is to preserve every inch of length of the tibia, even if one thinks that walking with the knee flexed will be ultimately inevitable; if there be a freely moving elbow joint to save it; to retain as great a length of thigh as possible; and even in the humerus, to preserve the head of the bone,

which by maintaining the breadth of the shoulder will give a better hold for the artificial arm than if disarticulation through the joint had been performed.

In these cases, then, we must make up our minds to do incomplete operations, to perform amputations which are not always clear of the area of diseased bone, and which, consequently, it will sometimes be necessary to retrim. An attempt must be made to free muscles in such a way that they may fill up and adhere to the walls of excavated bone cavities. And if at the same time, by a few sutures, the healing of the skin can be so arranged as to avoid return of troublesome puckering, then the obligation to see that drainage is adequate and satisfactory is increased, because post-operative recrudescence of infection with the appearance of foul discharge, and even sloughing of the soft parts, is not uncommon.

The infection of wounds of war is much more lasting, much more obstinate than that in any wounds we have had experience of in civil surgery; and several times after very late secondary amputations I have had to re-operate because of rapidly spreading acute inflammation, and then later still to operate again to remove the sequestra thus produced or to excavate a diseased cavity. Such operations, of but little operative brilliance, followed by prolonged and tedious after-treatment, have resulted in my obtaining in the end stumps that are very much more useful than such as would have resulted in much less time from an originally higher amputation through healthy tissues.

I have now dealt at quite sufficient length with osteomyelitis of amputation stumps; there remains—

although it lies rather outside the range of bone lesions and infective complications—the subject of the retrimming of amputation stumps on account either of some defect of the soft parts or of amputation neuromata.

The general shape of the stump, the position of the scar, the thickness of the soft parts around the bone end, should be studied in their relation to the artificial limb that is to be worn. Troubles connected with these points are of course much more frequent in a stump that has suppurated, but often also they arise from defects in technique that I should like to mention, and they furnish indications for operative interference which, less absolutely important than those furnished by the still suppurating stump, are nevertheless often quite urgent.

A stump is really satisfactory only when the scar is supple and protected from pressure by the artificial limb, when the end of the bone is well covered with muscle, already atrophied and destined soon to become fibrous, and the skin freely movable over the underlying tissues and not tense. Now we often see stumps which fail to fulfil these conditions satisfactorily ; they are not suppurating or ulcerated, but they are sufficiently conical to be very troublesome.

In the thigh and in the arm it frequently happens that the bone for 3–4 cm. is surrounded by skin only, the muscles having retracted up for this distance above the badly covered bone end. Often the skin itself is too scanty and tense—*e.g.* in thigh stumps shaped like the nose and mouth of a shark, conical, with the scar far up on the posterior surface.

In the arm the stump has no pressure to transmit

along its vertical axis; it has only to communicate movement to the artificial limb. Hence the inconvenience of an arm stump, which is incapable of bearing pressure, is not so great; but in the thigh things are very different if advantage is to be taken of modern improvements in artificial limb making, *e.g.* the transference of weight bearing from the tuber ischii to the stump itself, the surfaces and tip of which fit exactly into the rigid wooden bucket.

What obviously is of the utmost importance is the careful preservation of a length of stump at least sufficient to assure a firm hold on the artificial limb, and to guarantee its subsequent efficient action as a lever; but when amputation is performed in the lower third or quarter of the thigh, one need not be guided solely by consideration of the subsequent length of the stump; here a good supra-condyloid amputation is better than a disarticulation through the knee joint, over which the skin is tense and thin.

In the leg one of the most frequent defects results from a badly performed original division of the bone; the tibial crest has not been bevelled off, and constantly gives trouble under the thin skin covering it; or the fibula has been cut at the same level as the tibia or even lower. If to these be added an adherent terminal scar, the result of suppuration or of a circular amputation leaving insufficient covering for the bones, the stump will certainly be incapable of bearing weight. Inconvenience of this sort of course is less important when it occurs in the upper part of the leg—formerly known as the seat of election—if the old apparatus allowing of walking with the bent knee be used; but it is very considerable in modern limbs to which the stump transmits pressure along its vertical axis, and

which allow of more or less free movement of the knee joint during walking. It is necessary in such cases to shorten the bones, especially the fibula, and to remove the tibial crest; at the same time, whenever possible, the opportunity should be taken of providing the bones with a skin flap lined with a good thick layer of muscle. I am among those who recommend as a general principle flap amputations for the leg: in the lower half a large posterior flap is best (the elliptical method of amputation here gives a very good result); in the upper half the choice lies between a long external and a long posterior flap.

Before leaving the subject of amputation stumps, I will deal shortly with amputation neuromata—spindle-shaped swellings very sensitive to pressure that develop on the cut ends of nerve-trunks. They almost always result from the omission of a detail in the operative technique of amputations: the surgeon has forgotten to look for the individual nerve-trunks of the segment of the amputated limb. When found, each should be drawn down for 3 or 4 centimetres of its length, and cut across in such a way that its proximal end retracts up out of sight among the muscles there definitely out of all danger of involvement in the scar.

Amputation stumps of the arm are the commonest sites for these neuromata, which occur most often on the median and ulnar nerves. They are found very rarely after amputation of the forearm, leg, or thigh. Such neuromata prevent the use of an artificial limb, and hence their removal becomes necessary—a secondary resection of the nerve-trunk, very easily and satisfactorily carried out through a short longitudinal incision.

These cases of neuromata in the arm may be compared with a nerve lesion that develops sometimes after amputations about the foot (sub-astragaloid disarticulation, Syme's amputation, Pirogoff's amputation, etc.), in which a long plantar flap traversed by the posterior tibial nerve is used to cover the bone end. If one omits to dissect out this nerve from the whole length of the flap, cutting it across at the level of the base of the flap, its presence will often prevent the essential direct transmission of weight through the stump. It is much more difficult to rectify this than it is to set right a simple neuroma; the nerve indeed may be excised by an incision through the plantar flap, but this will result in a painful, or at least a troublesome scar; the best method is again to turn back the whole flap and resect the nerve from its deep surface.

### 3. Sinuses resulting from Wounds of Bone and Compound Fractures

Fractures with an open wound, much more common to-day than ever before, do sometimes heal without suppuration, just like simple fractures. All civil surgeons engaged in hospital practice know this, and they no longer trouble themselves to reckon up the number of their successes in such cases, especially in the V-shaped fractures of the tibia. But all surgeons know that when suppuration does occur things are very different, and that treatment is then to be divided into three stages: first, the arrest of infection; second, securing union in as good a position as possible; and third, the treatment of the phenomena of chronic osteomyelitis, often so tedious and obstinate.

Again, we have not been surprised that many gunshot fractures, almost exclusively indeed those caused by bullets, have healed without suppuration, just as do many cases of bullet wounds of the soft parts only. But we have been astonished that compound fractures, which are united but still have open sinuses, are apparently often regarded as almost cured, as " slight cases " suitable for transference to non-surgical institutions where any medical man can insert a drain and give at need a scrape with a curette.

And treated so, many sinuses will go on for ever : I have seen some last for months and for years before they are submitted to a suitable operation, after which they almost all heal up in two or three months. These patients, I hold, are serious cases that require the services of a well-informed surgeon, an operation which is tedious, laborious, and often difficult, and afterwards careful dressing and assiduous attention. They should be kept constantly under the care of the surgeon who performs this operation ; transference of these cases to the care of other men is strongly to be deprecated. With the concurrence of the directors of the medical services in Paris I have succeeded in keeping in touch both with patients whose fractures I have treated from the first, and also with those who, after a longer or shorter period with open sinuses, have eventually come under my care, in each case right up to the completion of their ultimate and final cure. From the two hospitals for " the severely wounded " under my charge I have been able to evacuate such cases after operation to suburban hospitals. In these no operations are performed, but here I see the cases two or three times a month, and re-admit thence any in need of further operative treatment.

For it must be understood before undertaking the treatment of these cases that secondary operations are often necessary, that after more or less sound and apparently final healing relapses, which may be chronic, sub-acute, or even acute, are common. This is in accordance with the well-known clinical and operative history of chronic osteomyelitis. In order to progress from the simple to the more complicated I will first say some words about wounds of bones, and will then devote myself to fractures.

## A. Wounds of Bones

(*a*) *Wounds of the shafts of bones* are not common, for a projectile which strikes the compact bony cylinder of the shaft almost always fractures it completely. However, the following types are occasionally seen :—

1. A bullet or shell splinter without opening up the medullary canal cuts a groove of varying depth either more or less in the direction of or else at right angles to the long axis of one of the surfaces of the shaft.

2. A rifle bullet—and especially a round lead shrapnel bullet—when spent may flatten itself out against a bone, sometimes causing a simple contusion of the surface of the shaft, more often burying itself in and splintering the bone.

A simple bony contusion with infection of the neighbouring soft parts is almost identical with the condition that occurs so often in cavalry regiments from the kick of a horse against the inner surface or crest of the tibia.

The affected piece of bone, bared of its periosteum,

lies at the bottom of a suppurating wound and undergoes necrosis over a varying extent and depth, and finally forms a thin scale-like sequestrum with one surface—that originally superficial—smooth, the other irregularly eaten away, and with its edges everywhere serrated by the process of rarefying osteitis.

Except in cases complicated by severe inflammation of the soft parts, diffuse osteomyelitis and extensive necrosis result but rarely ; one might therefore be led to expect an early spontaneous elimination of so superficial a sequestrum at the end of the five or six weeks necessary for its liberation.

Often indeed things do happen thus, especially in the skull, allowance being made for the relative frequence in simple contusion of associated fissures of the vault or of comminution of the inner table. One can here observe the imperceptible exfoliation of the bone, the surface of which at first white, smooth, and bare, becomes little by little flecked with red spots, and later uniformly covered with granulations. In other cases the sequestrum loosens and comes away almost without the aid of forceps. Sometimes, however, the sequestrum is larger than the cutaneous opening of the corresponding sinus, which has then to be enlarged with the knife before the curette can be used. Rarely do its borders become caught in an overgrowth of new sub-periosteal bone ; and even in these rare cases it generally manages to escape, so that, on the whole, such cases are of little practical importance. Operations should not be performed until the sequestrum is loose, for until this has occurred it is impossible to be certain of its size ; premature operations are thus likely to do too much or too little, either to remove the whole thickness of the bone when the deeper part

would otherwise have survived, or else to leave edges which necrose later and necessitate re-operation.

A contused wound of the superficial surface of the tibia is often of a discouragingly chronic nature, less because of enclosure of the sequestrum than because of delay in healing of the soft parts. There has perhaps been considerable destruction of the skin, which here is thin and stretched over a bone that possesses but little subcutaneous covering. Epithelial ingrowth over the granulating surface of the bone makes little or no progress, and when healing does take place, the scar is thin, adherent, badly nourished, and liable to frequent ulceration.

Treatment should consist in excising the ulcerated patch right down to the bone, in scraping away granulations from the surface of the bone, and in the removal of sequestra. The bony surface should be scraped until healthy bone is exposed, and then, after suitable undercutting, the skin should be sutured and the wound thus closed ; as in all cases where secondary suture of a wound that has suppurated is attempted it will be wise to insert a drain.

When sequestrum formation follows contusion of a bone lying deep under a thick muscular covering, *e.g.* in the shaft of the femur, a sinus results which frequently keeps on discharging for months until the necrosed bone is exposed and removed. The edges of such a sequestrum are frequently overlapped by new sub-periosteal bone, but usually this is of no great extent or bulk, and there exists no real sequestral cavity. The operation will thus consist merely in slitting up the sinus track so as to allow of the detachment and removal of the sequestrum—easily effected by one stroke of the curette ; despite the thickness

of the soft parts, the conditions are the same as we have described in the case of the skull.

Before operating the surgeon may, if he so please, ascertain whether the track leads to bare bone or not, but in these cases where so long a track runs through so great a thickness of muscle, it is not nearly so easy as in the skull to make certain whether the sequestrum be loose or not. This operation differs very much from the much more serious one that becomes necessary when a cavity remains in the bone after the removal of all sequestra.

When the sinus, although at first sight apparently indistinguishable from those with which we shall deal later, leads to bone that is not thickened, when on examination new bone formation is found to be absent, and when the probe does not seem to enter a bony cavity, the presumption is that the sequestrum will be found to be superficial, with but little sub-periosteal encasement. The information furnished by radiography is interesting; the X-ray plate shows a bone of normal density without any transparent central patches; its edges are clear cut, straight, and without irregularity except at one definite spot, where may be seen the dark shadow of the sequestrum that is being liberated by rarefying osteitis, its inner border at present but imperfectly distinguishable from the irregular surface of the bone itself, whilst no shadow of newly-formed bone appears on its outer side. This gives information which is interesting but not always reliable, since a bone may contain many sequestra deep in its shaft, and yet give an almost normal appearance on an X-ray plate. Still an experienced eye will usually succeed in detecting slight points of abnormality. I shall return to this point later when dealing with the radiographic

characteristics of bony cavities and of enclosed sequestra.

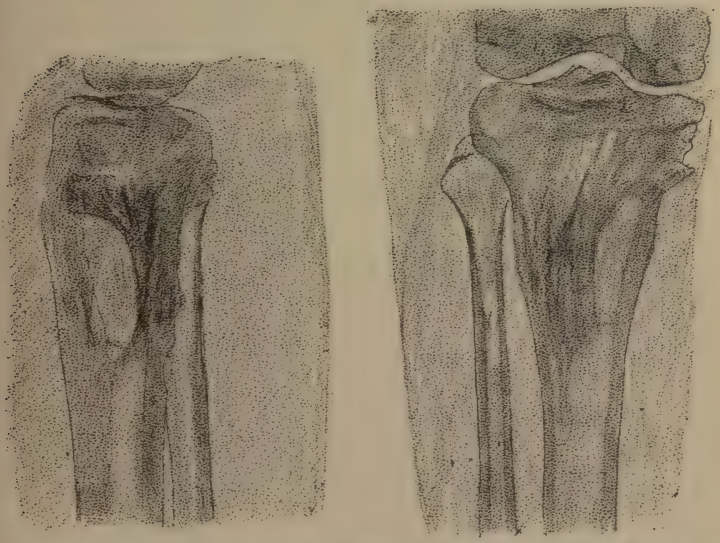
Traumatic furrows and incomplete fractures limited to one surface of the shaft of a long bone may end similarly with the formation of superficial sequestra, but often—and more especially in the cases where there is splintering of the shaft—these are complicated by fissures opening into the medullary cavity and fragments either partly adherent or completely detached. If at the same time, and on the top of such a state of affairs, infection is introduced and becomes active, the osteomyelitis that results runs a course, and has consequences which do not differ from those that occur in compound fractures without displacement of fragments.

(*b*) *Wounds without complete fracture of cancellous bone, i.e.* of large epiphyses and the small flat bones, are not infrequent, and occur either in punctured wounds of the soft parts, or with a single entrance wound, the foreign body being retained. The projectile is sometimes a rifle bullet, sometimes a small piece of shell casing, or a round shrapnel ball.

Tracks from punctured wounds often do not suppurate; healing takes place in a few days, frequently after an effusion of blood has taken place into the neighbouring joint, especially often into the knee joint.

Suppuration, however, is usual if a foreign body, projectile or piece of clothing, remains in the track of the wound. The aseptic healing of a bullet or even of a piece of shell in an epiphysis does, however, sometimes happen; sometimes, too, there occurs but a slight limited infection, which soon disappears after the removal of the foreign body, even though this has remained in the bone for some time. Let no one, how-

ever, suppose that the occurrence of these favourable events is anything but unusual; rarefying osteitis is the rule (figs. 44 to 47), a process that usually spreads rapidly to all parts of the mass of spongy bone. A large cavity is then inevitable in a position which is



FIGS. 44 and 45.—Patient twenty-eight years of age; wounded, 3rd March 1915; perforation by a bullet of the upper tibial epiphysis. Radical operation, 25th August 1915. X-ray taken, 28th March 1916. Healed by 6th April 1916, with free movement of the knee joint.

most unfavourable, both because of the inevitably prolonged period of healing, and also because of the frequency with which a chronic synovitis follows. Whilst, then, in the case of a bullet track with but tiny skin punctures it is expedient to wait before operating until suppuration has definitely occurred, and not to commence seeking for hypothetical pieces of clothing—

nor even to submit such cases to any sort of continuous antiseptic irrigation—on the other hand, operation should be early, even immediate, in cases where radiography shows the retention of a foreign body, and this is almost always the case in wounds with but one entrance. One will abstain from operation only





FIGS. 46 and 47.—Patient forty-one years of age; wounded, 25th September 1916, a piece of shell passing right through the soft parts and the upper tibial epiphysis. Caries without sequestra is shown spreading down a little into the shaft. X-rayed, 24th March 1916. Operation, 11th April. Still unhealed in September.

where—what does happen sometimes with bullets, and exceptionally with pieces of shell and broken bullets—the encysting of such a foreign body is already far advanced and the patient is free from all pain and all signs of subacute or chronic arthritis.

Nevertheless, even in these cases, if it can be done without much risk, I usually extract the bullet, for I

have learned by experience that although these foreign bodies may at first seem to be aseptic, later recrudescence of inflammation about them occurs very much more often than we believed in the early days of the war ; it is wise never to allow rarefying osteitis either time or opportunity to develop in an epiphysis, for even in cases where the infection is of the slightest, it is rare for the process to be localised by the occurrence of osteosclerosis around it.

### B. Compound Fractures with Chronic Sinuses

**Pathology.**—The chief characteristic of gunshot fractures is their comminution.

This includes two phenomena :—

(i) The complete shattering of the bone at the point of reception of the njury.

(ii) The accompanying fissures or cracks that radiate a variable distance up and down the shaft of the bone from the actual primary seat of injury.

One result of this is the extensive opening up of the medullary cavity, another is the production of a number of bony fragments at the point of injury ; of these latter some are from the beginning loose, unattached either to the main mass of bone or to the stripped-up periosteum ; others remain adherent, *i.e.* they are separated from the bone shaft, but still retain connection with periosteum, and through it with the neighbouring soft parts.

When the fracture is not compound, not infected, such an extensive shattering does not interfere at all with the final attainment of sound union. Not only do the adherent fragments survive and take an active

part in the union, but even the loose pieces join up with these and assist in the callus formation. It even happens more frequently than one might imagine, in fractures where the bullet has broken up into innumerable pieces, that these become set in the callus along with the fragments of bone. In such cases this callus of course remains for a long time excessive in amount and inflamed and painful; however, it does not suppurate, but gradually becomes remodelled and lessens in size, complete union and healing taking place without the necessity for any operative intervention, just as in a simple fracture. I shall return later to the radiographic appearances of these metallic fragments, which become so embedded in bone as to be really no longer foreign bodies whose extraction is either feasible or desirable.

However, if the seat of fracture is infected two processes must be distinguished :—

(i) The separation of necrosed bone.
(ii) The consolidation of the fractured bone.

1. *The separation of necrosed bone.*

It is inevitable that fragments which are from the first completely detached from all their connections should die and at once form sequestra. The same fate soon overtakes most of the partially adherent fragments, whose periosteal connection is not long in giving way. These two varieties of sequestra are of the same general shape—that is to say, their surfaces are smooth and clean, their edges and points sharp, without any of those fine serrations that are at once the outcome and the sign of a process of liberation by rarefying osteitis. Clinically they are almost identical, no great time having elapsed between the

immediate isolation of the former at the time of the fracture and the final and total denudation of the latter in the suppurating area.

As regards the two ends of the shaft, however, the pathological changes are different. They are the same as those we have described as taking place in the end of the bone in an infected amputation stump. The ends of the fragments, denuded as they are of their periosteal covering, undergo necrosis over a variable length. This necrosed bone in time becomes loose and then forms secondary sequestra, which show signs of their mode of production by the presence on their separated surfaces of those fine serrations characteristic of fragments set free by rarefying osteitis. Other secondary sequestra—usually quite small—are of a purely inflammatory origin. Like the sequestra of spontaneous osteomyelitis, these bear serrations on all their surfaces and edges. The clinical difference, then, between primary and secondary sequestra is due to the gradual isolation of the latter by rarefying osteitis : these pathological observations have a practical significance for the surgeon that will appear later.

I shall not repeat what I have already written in dealing with osteomyelitis in amputation stumps, about the occurrence, to a greater or less extent, of infection of the medullary cavity, and about the involvement of neighbouring epiphyses in the septic process. The simultaneous involvement of both epiphyses takes place only in such cases of complete shattering of the shaft as is practically incompatible with the preservation of the limb. Usually a fracture near the middle of a shaft is not complicated by extension of the infection to the epiphysis. This

does, however, sometimes occur, especially when the bone has been fractured near the junction of the shaft with the epiphysis, where the medullary canal has come to an end and the compact bone of the shaft is gradually being replaced by a trabecular structure of cancellous bone.

2. *The consolidation of the fractured bone.*

Union of the fragments of the bone takes place side by side with the liberation of the secondary sequestra. It is effected partly by intermediate callus, partly by callus uniting those parts of the shaft that lie beyond the area of necrosis, and partly by sub-periosteal new bone formation. This last plays the chief part in the union in cases where necrosis of the fragments of the diaphysis has been extensive, and also especially in cases where union is taking place despite marked angulation. In this way we get produced a sheath of new bone, and a sequestral cavity in which the various sequestra lie enclosed. This cavity communicates with the tissues lying outside the bone by perforations of variable size and number in the encasing sheath of new bone. Often there is but one such perforation of spontaneous origin, that has been in existence from the earliest days of the fracture. After operations have been performed for the removal of sequestra or foreign bodies, however, they are frequently more numerous and of larger size.

Whether the fragments are in good or bad position, with or without angulation, the mode of formation of the cavity, by the laying down of sub-periosteal callus, remains as a general rule the same. But the amount of the callus, the dimensions and shape of the cavity, vary greatly with the accuracy of reduction of the fracture.

The simplest case is that in which the fragments lie end to end without any displacement; in such it is rare for the infection to be extensive; the two fractured ends unite; a considerable length of the medullary canal of each becomes obliterated by a process of condensing osteitis similar to that we have seen taking place in amputation stumps; around the ends of the two fragments the sheath of sub-periosteal new bone becomes compact and dense; the sequestra are usually small, and granulation tissue but slightly in evidence.

When the loss of bone has been extensive but the periosteal sheath well preserved, and when union with gross displacement or malposition has been avoided by adequate immobilisation, then the bone will unite, with shortening certainly, but with little or no angulation; apart from this shortening, however, a condition of affairs very similar to that we have described obtains, except that the cavity will be larger and more irregular, the sequestra bigger, and the production of sub-periosteal callus excessive. The two ends of the bone coming into some sort of contact unite over at least a part of their surface, and intermediate callus still plays a not unimportant part in the attainment of union. In such cases, when early operation, undertaken on account of serious infective complications, has cleaned out the infected seat of fracture, shortening is inevitable; nevertheless by the use of suitable apparatus and careful attention, especially by continuous extension in fractures of the femur and humerus, a good result may be obtained, union resulting without angulation, the sequestral cavity that remains being usually of a type in which rapid final cure is not difficult to secure.

The conditions are very much less favourable, however, when overlapping and angulation occur; such still too frequently result in fractures of femur, partly because it has not been possible to obtain reduction of the fracture, partly on account of some inadequacy or defect in the immobilisation. It is not always possible, for instance, properly to reduce or immobilise a sub-trochanteric fracture complicated by considerable comminution and by the presence of severe inflammation that necessitates multiple long incisions. In such a case the fragments remain only in very poor contact; intermediate callus becomes an agent of only secondary importance in the union, the chief part being played by a deposit of new bone in successive layers from the periosteum that has been stripped from the shaft for a variable but always considerable distance up and down. In such a case the sequestral cavity that results is of most irregular shape, with walls of new bone of great, sometimes enormous, thickness. This new bone is for the most part dense, attaining in the course of time to an extreme degree of hardness. In some places, however, this is not so—it is rarefied, excavated by pus or granulation tissue; in other places it is hollowed out into small abscess cavities and tunnels that become lined with granulations.

In these cases also there may take place a great extension of the osteomyelitis, with the formation of very long sequestra, which may even extend to almost the entire length of the diaphysis, sequestra which are identical in their appearance and in their origin with those occurring in spontaneous osteomyelitis.

It is this type of case, too, in which the chronic

infective process, if left to itself, tends to spread, so that unless it be cut short by a radical operation, more and more bone becomes converted into granulation tissue, and the cavity undergoes a progressive increase in size.

This persistence of the inflammatory process should not be forgotten; slow doubtless it is, but characterised by no natural tendency to cease, involving the late development of sequestra in places originally altogether outside the seat of injury and infection. It thus produces a gradual increase in the extent and severity of the bone lesion. Attacks of subacute, if not of acute, osteomyelitis often supervene, hence this traumatic process follows the classical course of the spontaneous osteomyelitis of childhood. Just as in this latter disease, so in this traumatic form, the extension of the pathological process into an epiphysis may result in serous, plastic, or suppurative arthritis of the neighbouring joint. Even in the absence of such an arthritis, however, the range of movement of the joint may be seriously limited by the overgrowth of the articular end of the bone.

Sequestra large or small are an almost invariable occurrence; in no case that has been under my care from first to last have they been entirely absent, and in hardly any that have come to me later with open sinuses, and in these rare cases there has always been present a cavity from which they had either spontaneously emerged or been surgically removed. The persistent sinus in such cases is due to the persistence of osteitis, to the existence of a suppurating cavity, the obliteration of which should be at least as much the object of operation as the removal of sequestra.

As regards flat bones, I have already said that the enclosure of sequestra is but rarely of importance in the skull. Such is not the case, however, with the innominate bones and scapulæ, in which the sequestra do become enclosed in cavities formed by sub-periosteal deposit of bone. This occurs constantly in traumatic lesions of the iliac crest and of the angle and the axillary border of the scapula. In the scapula, too, it is quite common to find a cavity or tunnel containing sequestra in the cancellous mass at the attachment of the spine to the body of the bone. As regards short spongy bones, especially the larger bones of the tarsus, I have nothing to add to the description I have already given of the formation in them of cavities, often containing sequestra, by a process of widespread caries. But I wish to insist on the occurrence—almost inevitable in these cases—of infection of the neighbouring joints, on the obligation to anticipate more or less ankylosis of such joints, and hence to take steps to prevent the development of such positions as will, on the occurrence of ankylosis, lead to poor functional results. I shall deal with this subject later.

This applies also to all infected fractures of epiphyses in which the corresponding joint suppurates and later undergoes complete bony ankylosis, and in which the maintenance of the "ideal" position of election of the limb is a matter of the greatest importance. The persistence of a chronic sinus in these cases is due, however, not to the joint lesion but to caries of the epiphysis.

## THE RADIOGRAPHIC STUDY OF TRAUMATIC OSTEOMYELITIS

We shall not enter into a theoretical discussion of the interpretation of the radiographic appearances of various bone lesions ; two brief statements of fact will serve as a *résumé* of the subject :—

1. Caries or rarefying osteitis produces areas of abnormal permeability to the X-rays ; these appear in a negative[1] as irregularly shaped dark patches, separated by the lighter bars and areas that correspond to the intervening portions of denser bone.

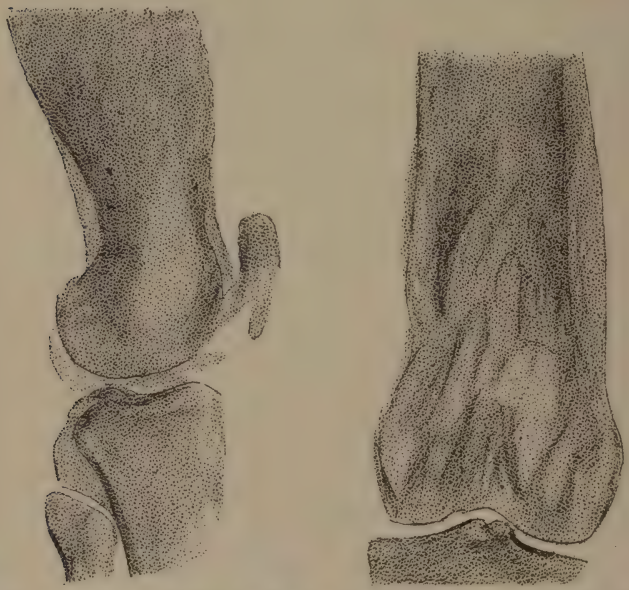
2. Sequestra, on the other hand, are abnormally opaque and impermeable to X-rays ; hence these show up in a negative as very light spots, often recognisable by their pointed ends and clean-cut, often serrated, borders. They are less opaque by far, however, than metallic fragments ; but it is important to remember that a piece of metal, especially a piece of lead, that has struck and fractured a bone can so coat a fragment of bone—sequestrum or not—with a thin metallic layer as to make it as impermeable to the rays as the foreign body itself.

If the skiagram of a bone, the seat of an old-standing spontaneous osteomyelitis dating back to childhood, be first examined (figs. 48 and 49), these inequalities of transparency will appear very evident ; it will be noticed besides that the bone is generally enlarged and irregular in outline—this because outside the original shaft that throws a dark shadow of quite normal shape there appears a distinctly lighter

[1] If one is examining a print and not a negative, of course the reverse holds good—parts impermeable to the X-rays appear dark, parts abnormally permeable, light.

shadow of irregular outline due to the presence of an involucrum of sub-periosteal origin (fig. 48).

A first type is represented by rarefying osteitis,



Figs. 48 and 49.—X-ray appearances in a case of hyperostosis, with intermittently discharging sinus in an adult who suffered from a chronic osteomyelitis dating from childhood. No sequestra. The unequal patches of rarefaction and the distinction between the original shaft and the new sub-periosteal bone are clearly seen. Note the club-shaped enlargement of the condylar and supra-condylar region, common in these cases, and the principal cause of stiffness of the knee in the extended position. Compare this with the traumatic osteitis without sequestra (and without hyperostosis) in figs. 50 and 51, and the different appearances when there are little sequestra in the cavity (figs. 52 and 53).

without sequestra—these may have been removed or may never have been present—following the penetration without complete fracture of an epiphysis



FIGS. 50 and 51. Patient aged twenty-nine. Wounded with shrapnel, 18th September 1914. X-ray, 18th March 1916, after a radical operation performed on 26th January 1916. Healed by the end of April.



FIG. 52.—Patient aged twenty-seven. Wounded on 17th December 1914. X-ray, 27th January 1916. Radical operation 1st February. Sinuses still present in September.

(figs. 50 and 51 ; see also pp. 69, 70), or from the penetration of a diaphysis, no sign remaining of any fracture, although there may originally have been longitudinal fissuring or a transverse fracture without displacement (figs. 53 and 54). Attention should



Fig. 53.—Wounded, 18th November 1914. X-ray, 25th February 1916. Radical operation, 28th February. The cavity extended very far downwards. Healed by 30th May.

be directed in these radiograms to the great extent of the cavities existing in the epiphyses or encroaching on the shaft. There appears in them no appreciable amount of new sub-periosteal bone. Figs. 55–60, on the other hand, show both displacement of fragments and more or less deposit of sub-periosteal bone. Figs. 55–60 and also 53 and 54 show the presence of cavities

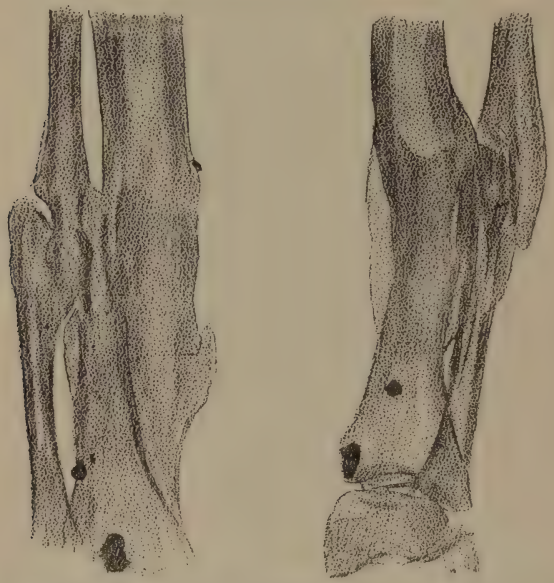
containing numerous sequestra—the latter recognisable by the dark shadows they throw, much less dark, however, than those of metallic fragments. Fig. 56



Fig. 54.—Patient twenty-four years old. Wounded, 22nd August 1914, by a shrapnel bullet; refused to allow his leg to be amputated in Germany on the eighth day. X-rayed, 26th February 1916. A cavity of great extent is present in the shaft extending down further than the X-ray would lead one to expect. A first operation was performed 2nd March 1916 and three sequestra removed. The lower end of the wound remained open as a sinus, and on re-operating on 30th May, and again on 12th July, small narrow cavities lined with granulations were discovered still further down the shaft, on the latter occasion extending to within two finger-breadths above the malleoli. Healing was complete by 25th August 1916, the scar remaining adherent to the groove in the bone and covered with very thin skin.

shows two small fragments embedded in the lower end of the tibia. In fig. 54 one sees a cavity in the shaft containing sequestra, the fracture having

united without displacement. In figs. 56–58 displacement of fragments is shown and the sub-periosteal new bone taking part in the formation of the sequestral cavity. Figs. 55–58 are also examples of fracture of



Figs. 55 and 56.—Patient thirty-three years old; wounded by a piece of shell on the 1st March 1915; attempt at suture on 16th March; profuse suppuration; several operations for the removal of sequestra. 7 centimetres of shortening; a sinus still persisting. X-rayed on the 25th March 1916. On the 12th of April a radical operation was performed; a condition of osteitis was found, but no sequestra; the diseased bone was removed. This patient was still under treatment and unhealed in September.

the two bones of the leg ending in a synostosis; whilst in fig. 54 it will be noticed that the soundness of the fibula has been effective in preventing displacement of the fragments of the tibia.

## CLINICAL STUDY.

An increase in the size of the bone and the presence of a discharging sinus constitute the two chief clinical signs of traumatic osteomyelitis.



FIGS. 57 and 58.—Patient, twenty-one years old, was wounded on the 27th of September 1915. The diseased bone was scraped on the 18th March 1916. X-rayed on the 23rd of March; cavities of both the tibia and the fibula are shown, containing sequestra. Radical operation performed on the 5th of April 1916; healing complete by the 13th of June.

This increase in the size of the bone varies greatly in different cases; in most it is considerable, in a few enormous, especially where mal-union has occurred with overlapping or marked lateral displacement of fragments.

When it involves the middle of the shaft the bone becomes spindle-shaped ; when one end of the shaft, this end becomes club-shaped—the shaft greatly thickened towards the epiphysis, but in the opposite



Fig. 59.—Patient, thirty years of age, was wounded in Serbia on the 25th of November 1914. X-rayed on the 26th of February 1916. A cavity in the bone lined with granulations but without sequestra. Operation on the 2nd of March ; healed by the 30th of May. The sinus opened again with slight suppuration on the 31st of July, and did not heal until the 19th of August. Walking is rendered difficult by the existence of a laxity of the ligaments of the knee joint resulting in a genu recurvatum that is quite apparent during standing.

direction, gradually decreasing in diameter until normal thickness is reached at variable distance toward the far epiphysis.

Hyperostosis of the whole shaft, with a thicker



Fig. 60.—Patient thirty-one years old, wounded by a piece of shell on the 1st of March 1915. Removal of fragments on the 23rd of April 1915. Sequestra are lying in the midst of the interfragmentary callus. X-rayed on the 24th of March 1916. Operation on the 2nd of April; scraping of the upper fragment, which was projecting beyond the lower downwards and outwards; rarefying osteitis of the lower fragment. Finally healed in July.

Fig. 60 represents a type of fracture with great displacement and overlapping in which the callus is almost exclusively periosteal, in which there is no real contact of the actual fractured surfaces, and in which the sequestrum is enclosed in the periosteal callus lying between the bone-ends. It should be noted that the process of rarefying osteitis of the lower fragment did not extend nearly as far as the epiphysis, and that healing took place relatively quickly; on the other hand, this may be contrasted with the uncertainty and slowness of healing in cases where the cancellous tissue is affected (figs. 46, 59, 61, for example).

mass at either end, is seen only in cases where there has originally been a complete shattering of the whole diaphysis; this is rare, as such cases usually end sooner or later in amputation.



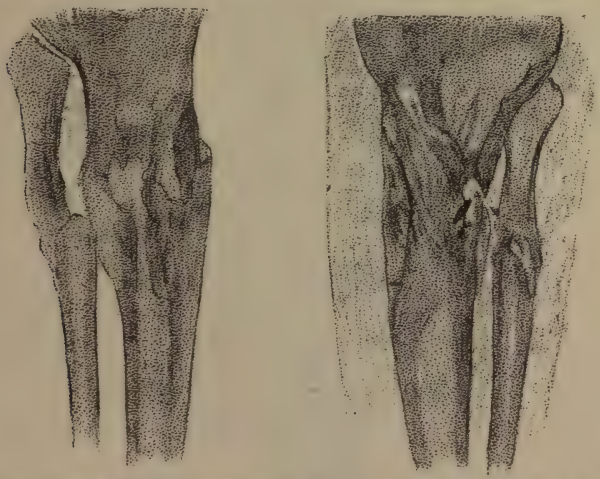
EXAMPLES OF SEQUESTRA ENCASED IN SEQUESTRAL CAVITIES OF THE SHAFTS OF LONG BONES.

FIG. 61.—Patient aged thirty years; wounded by a bullet on the 20th of September 1914. A cavity remains containing one sequestrum despite three operations (in Germany). Rarefying osteitis of the epiphysis. X-rayed on the 25th of February 1916. Radical operation on the 3rd of March. Still discharging in September.

On inspection the increase in size and the abnormal shape of the bone are seen, but their full extent may not be appreciated, unless it is remembered that when the limb, which is so abnormally cylindrical, and whose

natural prominences are lost, is further examined, it will be found that the muscles are much atrophied.

On palpation, however, the irregular mass of bone will be felt immediately under the skin, presenting in many cases marked projections that may be recognised as the original ends of the displaced fragments,



FIGS. 62 and 63.—Patient aged thirty-three years ; wounded by a bullet on the 11th of October 1914. Several times scraped. A cavity remains containing six large sequestra. Operation on the 7th of April ; healed by the end of April ; on the 5th of May, however, another sequestrum appeared, the sinus being healed again by the 26th of June.

rendered, however, smooth and regular in outline by subsequent deposit of sub-periosteal callus. The whole mass is of bony hardness ; the skin over it, hotter than on the opposite side, is thickened, infiltrated, and unyielding, and the seat often of a solid chronic œdema of inflammatory origin. In some cases pain is present intermittently, in others almost completely or entirely

absent; in some cases on palpation the bone is quite insensitive, in others special localised areas remain extremely tender.



Fig. 64.—Patient aged thirty-three years; wounded by shrapnel on the 18th of January 1915. X-rayed on the 23rd of March 1916. Operation on the 8th of April with correction of stiff contracted toes. Recommended for discharge from the Army; still with a superficial sinus on the 21st of July.

Note in this case: first, the pieces of lead scattered through the lower fragment of the tibia; second, the sequestrum in front of the tibia; third, the obliquity of the lower fragment downwards and forwards, a displacement that necessitates flexion of the knee if the sole of the foot is to be put flat to the ground (see Chapter V.).

This abnormal mass of bone communicates with the exterior by means of one or more sinuses that open either through the original wounds of entrance or exit, or through one or more of the tracks due to early abscess formation, or through which a later

and more chronic abscess has been opened. It should be understood that I am not speaking of sinuses that

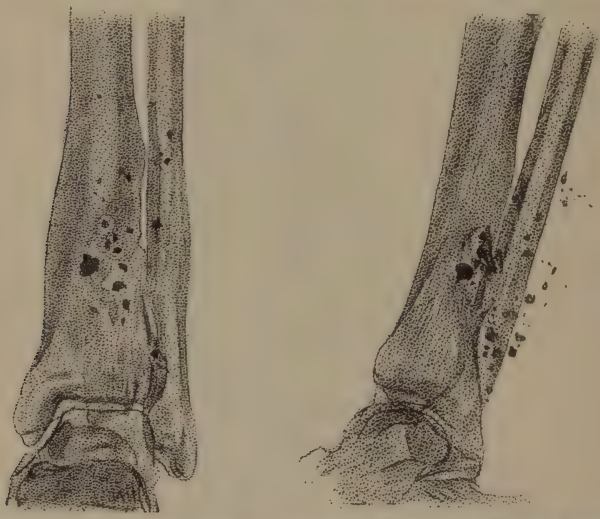


FIG. 65.—Patient of thirty-six years ; wounded by a rifle bullet on the 26th of November 1914. X-rayed on the 29th of January 1916. Operation with removal of a sequestrum on the 15th of February 1916 ; healed by the 22nd of March.

Note the rapidity of the healing which results from the removal of the sequestrum encased in a cavity with compact walls. Note also the dislocation of the hip joint with disappearance of the femoral head.

result from operation undertaken for the cure of an old-standing focus of osteomyelitis ; in some cases these do remain open for a long time.

These sinuses almost always run a straight course to the bone. They commence at some point on a scar, which, usually soft and supple at its ends, remains thickened, hard, of a brownish colour, and inverted



RADIOGRAMS SHOWING THE PRESENCE OF SEQUESTRA AND METALLIC FOREIGN BODIES (a shattered bullet, Figs. 66 and 67; small pieces of shell casing, Fig. 68).

FIGS. 66 and 67.—Patient aged twenty-six years; wounded by a rifle bullet on the 28th of January 1915. X-rayed on the 6th of April 1916. A cavity remains in the back of the tibia, containing two sequestra, non-invaginated. Fragments of metal from the shattering of the bullet. Operation on the 10th of April. Discharged, almost healed, on the 20th of May to a hospital for slightly wounded native soldiers.

to form a funnel-shaped depression around the opening of the sinus. This runs towards the bone, to which it adheres, through a thick mass of dense scar tissue, in which lie the remains of the muscles and tendons of the part. Rarely the cutaneous opening leads

almost directly to the bone without running a course through the soft parts ; this occurs where the affected portion of the bone is subcutaneous or nearly so, around epiphyses, over the internal surface of the tibia, the posterior edge of the ulna, etc.

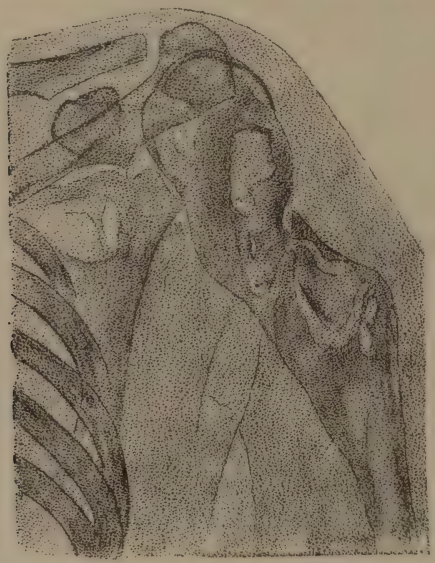



Fig. 68.—Patient aged thirty-six years ; wounded on the 7th of August 1915 by a piece of shell. A cavity persisted despite the removal of sequestra on the 18th of January 1916. X-rayed on the 9th of March 1916. Operation, obliteration of the cavity, and removal of the foreign bodies, on the 24th of March. Healing complete by the 11th of April. Stiff elbow with only 15 to 20 degrees of flexion and extension.

S, sequestra ; M, metallic foreign bodies.

The discharge from these sinuses is sometimes serous, sometimes thick pus ; in some cases abundant, in others scanty. Sometimes all that appears is a dry crust adherent to the scar. At first this may be con-

sidered the covering of a superficial ulcer—actually a not uncommon condition to find in the last stages of these cases, but on removing it, the point of the probe soon finds its way into the track of the sinus.



LESIONS OF THE UPPER END OF THE HUMERUS WITHOUT INVOLVING THE SHOULDER-JOINT.

FIG. 69.—Patient aged thirty-three years; wounded on the 5th of March 1915. X-rayed on the 1st of April 1916. Operation on the 12th of April (five sequestra); healed on the 21st of May.

On the 1st of September a small sinus reopened after the patient had returned home. The joint is quite free on passive movement, but active movement of it is absent owing to atrophy of the deltoid (probable division of the circumflex nerve).

Even when there is but little discharge the surrounding skin is often inflamed, eczematous, covered with scabs, or else discharging serum or pus over quite a considerable area, sometimes indeed around

the whole circumference of the affected segment of the limb. Such a condition of the skin is often very chronic, persisting after the complete healing of the sinus itself, and sometimes, because of the discharge, leading to the belief that the sinus is still open ; such

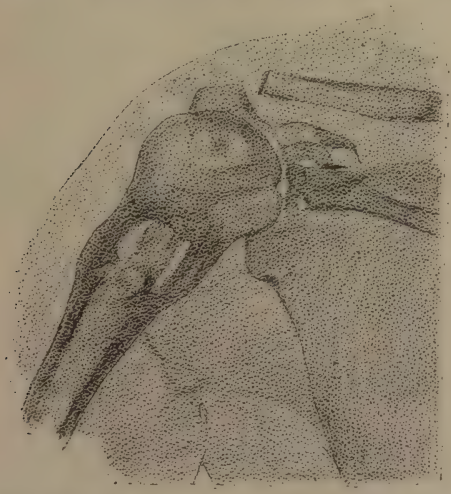


FIG. 70.—Patient aged twenty-two years ; wounded by a rifle bullet on the 20th March 1915. A granulating cavity persisted after the removal of sequestra for five months from the 15th of September 1915. The cavity, in which a thread of silk was found (? origin) was scraped out on the 28th of February 1916. I thought that this would have been all that was necessary, but, a sinus persisting, I was forced on the 9th of September to remove the anterior wall of the cavity.

has been the actual state of affairs in several cases sent to me with the diagnosis of persistent old-standing sinuses. Usually the track of the sinus is so straight that the probe finds its way without difficulty to the bone ; almost always indeed bare bone can be felt. According to the condition present, the probe

gives the sensation of contact with a surface of bare bone, of scraping along the rough wall of a tunnel, of engaging in a mass of soft carious bone in passing through the trabeculæ of which the probe gives a special sensation of very fine crepitus, or, lastly, of contact with a loosely lying sequestrum.

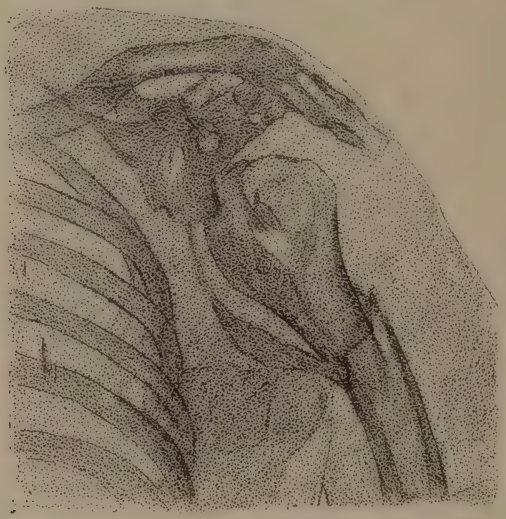


Fig. 71.—Patient aged thirty-six years; wounded by a bullet on the 13th of January 1915; fracture of the humerus; a cavity formed at the base of the glenoid cavity. X-rayed on the 26th of March 1916. Operation on the 1st of April; healed by the 1st of August, after the persistence for about a month of a sinus posteriorly.

When struck with the probe necrosed bone gives a clear, sharp note. To determine with the probe, however, whether or not such necrosed bone is loose, forming a sequestrum, is not always an easy matter; an acute ear will detect in the sound produced by a sequestrum a special, almost metallic, note, whilst

the skilled hand will perceive that the bone gives a little with the probe, and thus possesses a small to-and-fro movement. But we can be quite certain of this mobility only in those rarer cases in which,

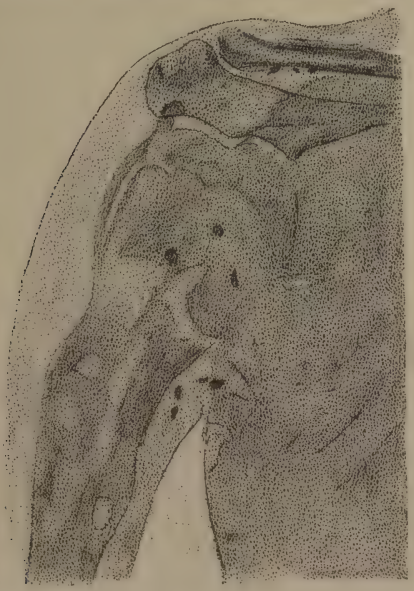
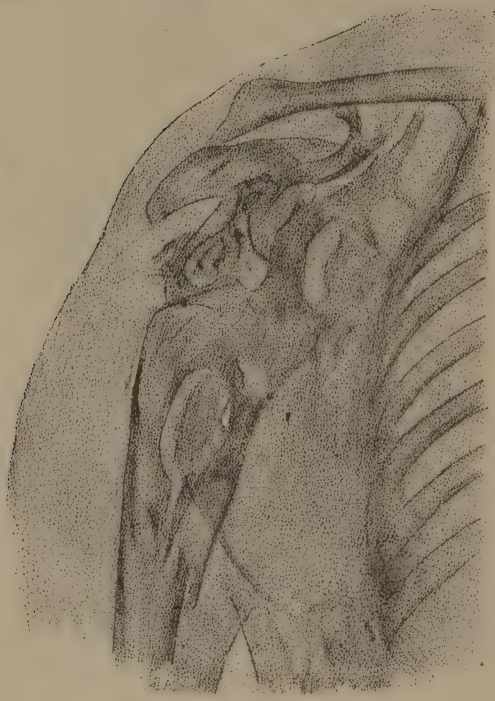


FIG. 72.—Patient aged thirty-three years; wounded by a bullet on the 25th of March 1915; had already submitted to three operations. X-rayed on the 15th of April 1916. Radiogram shows a large cavity due to rarefying osteitis without any sequestra. Radical operation on the 29th of April.

by introducing probes through two different sinuses into contact with the same piece of necrosed bone, movement can be transmitted from one to the other through the sequestrum.

When several sinuses are present, no matter what the position of their external openings and their

lengths, they generally all converge towards the same



Lesions of the Humerus and of the Scapula, with Bony Ankylosis of the Shoulder Joint.

Fig. 73.—Patient aged forty years; wounded by a bullet on the 12th of January 1915; six operations; ankylosis with the presence of sinuses; X-rayed on the 18th of April 1916. This man, who had eventually to be evacuated for misbehaviour, was a typical example of a case in which stiffness of the elbow and the fingers had resulted from the injudicious use of an arm-sling; free use of these joints was, however, spontaneously recovered in a few days, although the patient was not at all anxious to co-operate.

part of the bone, towards a single cavity with several cloacæ, and often, especially if the sequestra have

already been removed, the points of probes passed along two or more of the sinuses may be felt to meet.

It is not often possible with the probe to determine accurately the shape, directions, and size of the sequestral cavity; this is possible only in those cases in which the sinuses lead down directly into a cavity in a subcutaneous bone.

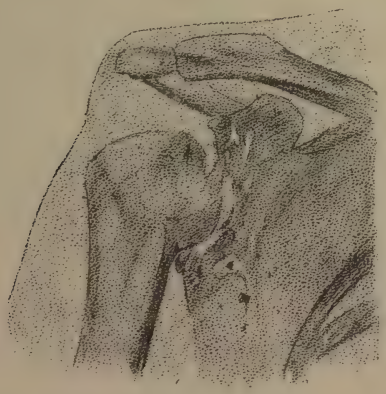
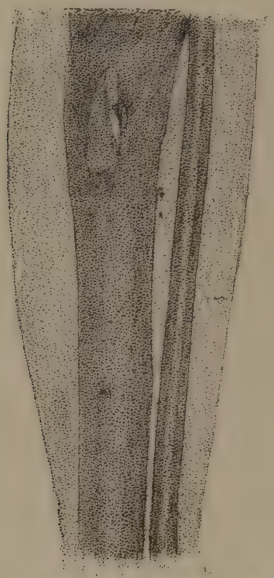


Fig. 74.—Patient aged twenty-four years; wounded on the 6th of December 1914. Removal of sequestra 25th of February 1915; X-rayed, 29th of March 1916. Rarefying osteitis without sequestra; operation, 27th March. He had to be evacuated for misbehaviour, 13th May, whilst still under treatment, although healing appeared to be progressing well.

In many, perhaps in most, cases small sequestra issue spontaneously from time to time from these sinuses carried out by the flow of pus, which during the few days preceding has usually been increased in amount and accompanied by more inflammation of the surrounding parts. I lay stress on this point, that the natural elimination of sequestra is a normal and usual occurrence in the course of chronic osteomyelitis,

whether traumatic or spontaneous : it is a phenomenon that has been familiar to surgeons for centuries, but it is just as well to remember this in present times, when certain claims based on its occurrence are being



CAVITIES WITHOUT SEQUESTRA discharging by a sinus, at first sight insignificant; the "cloaca" had been previously enlarged by totally inadequate scrapings. The probe passed into an extensive cavity.

FIG. 75.—Patient aged thirty-three years; wounded by a shrapnel ball, 25th September 1914. X-rayed, 18th February 1916; a sinus persists after an inadequate operation of conversion of the cavity into a gutter (four operations—scrapings—from October 1914 to April 1916). Obliteration of the cavity, 21st February and then again 5th September.

made on behalf of various therapeutic agents; with these I will deal later. It will be as well also to state explicitly, and once for all, that this spontaneous

appearance of sequestra hardly ever leads to permanent and ultimate cure. It may lead to an apparent local improvement, to a diminution of the suppuration; where in some cases the sinus does become smaller



FIG. 76.—Patient aged thirty years; wounded by a bullet, 25th September 1914; removal of sequestra, 12th December 1914. X-rayed, 20th January 1916. Cavity in the shaft without sequestra; operation, 24th January; healed, 30th April.

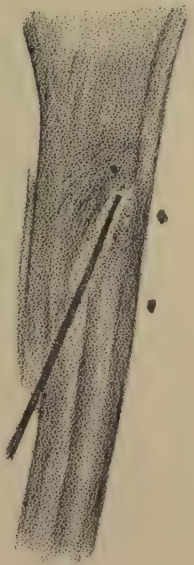


FIG. 77.—Patient aged twenty-three years; wounded by a piece of shell, 1st November 1914. X-ray, 11th May 1916; a large cavity with a small orifice; no sequestra; rarefying osteitis of the epiphysis. Operation, 30th May. Still a sinus in September.

or even heal, this results almost always merely in the formation of a new abscess, which again reopens the former track.

Only small, straight, sharp-pointed sequestra can emerge spontaneously in this way, passing first from the bone cavity through a cloaca into the track of the sinus, thence along the track to the exterior. A






SEQUESTRA LYING OUTSIDE THE CAVITY.

FIG. 78.—Patient aged thirty years; wounded by a piece of shell, 6th May 1915; never been operated on. X-ray, 9th April 1916; spontaneous issue of a sequestrum followed by a rapid cure.

FIG. 79.—Patient aged twenty-three years; wounded by a bullet, 22nd August 1914. X-ray, 18th April 1916; a large sequestrum removed, 5th May; healed by 1st September.

knowledge of pathological anatomy will render clear the mechanical conditions necessary to allow of this natural elimination (figs. 78 and 79).

Those parts of the limb, especially the lower limb, distal to the lesion often remain for a long period

œdematous, the skin cyanotic, the superficial veins engorged, and the muscles atrophied.

The function of neighbouring joints suffers in two different ways :—

1. Those joints immediately contiguous to an inflamed epiphysis either become involved in the spread of the inflammation, the result being an arthritis which may or may not suppurate, ending in fibrous or bony ankylosis, in good or bad position, or else become restricted in their range of movement by the enlargement and irregular shape of the end of the bone.

2. Those at a distance from the lesion may become fixed, often in a bad position, because of progressive fibrosis or contracture of muscles, because of the adoption of a bad position that has not been corrected sufficiently early, because in some cases of insufficient immobilisation, in other cases of inadvisable or too prolonged restriction of movement. This is specially the case in the joints of the fingers and of the foot.

This stiffness and ankylosis of joints, atrophy, contracture, and adhesions of muscles and tendons, form the subject-matter of a subsequent chapter. In conjunction with the common shortening of the affected limb they constitute the chief causes of functional disability. If it were not for these, and for the acute attacks of inflammation to which such cases are liable, this condition—chronic osteitis with persistent sinus—would be accompanied by but little pain or disability.

The occasional exacerbations of inflammation are usually accompanied by a certain amount of fever. But as a rule the temperature and general condition

of the patient remains fairly satisfactory. But such patients are often rather pale, and frequently their evening temperature may be slightly raised. One can hardly say that they are suffering from chronic septicæmia, but some slight degree of such a condition is usual in those who suffer from chronic suppurative lesions.

*Course, Duration, and Termination.*—In practically all cases the sinus dates right back to the early stages of the disease ; the early acute inflammation subsides, the area of osteitis becomes circumscribed, and the suppurating track settles down to form a chronic sinus which will persist until the focus of bone disease has been adequately and radically dealt with.

Where the seat of fracture has originally been exposed in a widely open and suppurating wound complete healing of the soft parts, even temporary, hardly ever occurs. Secondary sinus formation occurs only in those cases of fractures by bullets that at first appear to be uniting without suppuration, but in which sooner or later, especially where the foreign body has been retained, there appears a recrudescence of infection and inflammation. This is analogous to what occurs in the track of a bullet through soft parts in which has remained some fragment of clothing ; it is even more closely analogous to those simple flesh wounds in which a foreign body apparently long since " healed in " suddenly gives rise to a severe acute inflammation.

During the time when the wound of the soft parts is gradually contracting down to form a sinus the bone itself continues to increase in size until, in three to four months, union having taken place, it reaches what is practically its maximum, although, even

then, it still has a tendency to undergo a further slight but slow increase.

The condition at this point is that which I have described as typical of the disease; but on to this background of chronic inflammation we must add the occurrence at variable intervals of time of acute and subacute exacerbations, when the skin around the sinus becomes the seat of acute lymphangitis or even erysipelas, or when, in and around the bone, develop painful inflammatory swellings that in time either gradually resolve or else proceed to suppurate; in the latter case abscesses form of considerable, and sometimes of enormous size, with great quantities of pus of a foul odour accompanied by high fever and a serious general condition. In other cases an abscess forms slowly and without much pain or elevation of temperature; a diffuse induration—the skin over it showing a slight red blush—appears surrounding a part or the whole of the thickened bone; this after some time becomes soft and fluctuating at one spot, and unless incised and the pus evacuated, bursts and soon develops into another sinus; sometimes, however, on incising such a swelling one finds nothing but granulation tissue with a little sero-purulent or glairy fluid. These abscesses will be found to lead either to a perforation in the bony wall of a cavity, or simply to a bare surface of bone softened by rarefying osteitis.

For around the infected cavity this rarefying osteitis does not cease to progress. If left to itself, free from surgical intervention, it is not only incurable but even destined to make considerable headway. If, on the other hand, a sufficiently radical operation be performed at the suitable moment, final cure is the rule; it may be slow, and obtained only by long and careful

after-treatment, and even only after secondary operations. It cannot be too often repeated that cases of final healing following spontaneous elimination of sequestra—though such may occur with a superficial free sequestrum—must in practice be regarded as non-existent.

Even after cure by operation the patient's troubles are not necessarily ended; in the most favourable cases the existence of a large, densely adherent scar forms a very real disability, especially in those cases in which the scar, covered with but a thin layer of epithelium, remains adherent to the subcutaneous surface of a bone. Here, to a greater or less extent, it is constantly exposed to the danger of re-ulceration. Again, and worst of all, small foci of infection that may lie latent, deep in the bone for months or even for years, are liable to become active and form new abscesses and sinuses; it is true, however, that these foci are usually of but small dimensions.

This is in full accordance with the classical course of the spontaneous osteomyelitis of childhood, with the history of its chronic sinuses, with the revival of its activity, extending—especially when present in the lower femoral epiphysis—sometimes over the whole period of the patient's existence. Rational surgery is then of very great value in the treatment of this disease, but cure does not invariably follow, and in many cases one can never be certain that final cure —in the real scientific sense of the word—has been attained. In diffuse osteomyelitis, spontaneous or traumatic, the surgeon can only consider that the pathological process has ceased for the time being; one can never definitely affirm that it has been finally eradicated.

Regarded from this point of view, the osteomyelitis following the compound fractures of civil surgery always seemed to us on the whole less serious than the osteomyelitis of adolescence. Since the advent of antiseptic surgery we have only rarely seen in compound fractures acute diffusion of the infection up and down the shaft of the bone and the production of extensive necrosis; we have been accustomed to find only small localised sequestra lying in compact mass of new bone that healed readily and finally after their removal. In the compound fractures of this war, however, these serious complications have reappeared with a surprising frequence; the older surgeons have renewed their experience of, the younger have seen for the first time, these interminable after-effects of a diffuse traumatic osteomyelitis, associated at its commencement with an extensive inflammation of the soft parts, which may be more or less infiltrated with gas and gangrenous.

All this is due to many factors, some of which are inevitable, *e.g.* the extent and severity of the bone lesion, and the laceration of the soft parts; the inevitable original infection of the wounds contaminated by projectiles and by portions of extremely dirty clothing, the impossibility of securing for these wounded the treatment they so urgently need right in the front line at the time the wounds are sustained. But it is necessary to state that it is due in part also to a defect of organisation, to the frequent absence of an experienced surgeon from that surgical station at which, after an inevitably hasty dressing and removal from the dressing station, the wounded man ought really for the first time to be thoroughly examined and efficiently treated.

## CHAPTER III

## THE TREATMENT OF CHRONIC TRAUMATIC OSTEOMYELITIS

The treatment of bone sinuses resulting from gunshot wounds has too often been entrusted to physicians who, out of touch with surgical pathology and the operative inferences to be drawn from the study of it, have allowed the lesions to stagnate and grow worse. I have seen, too, many patients with chronic sinuses who, after being discharged from hospital with good union in a fracture which has been very well treated from the outset, are allowed to remain for months, sometimes for a year and more, without anyone dreaming of submitting them to further operations: some have had absolutely no treatment at all, others have been treated by hydrotherapeutic or physiotherapeutic methods, which is much the same thing, only often worse in its effects.

In many institutions "for the slightly wounded" treatment is restricted to the insertion of small drains or tents into the track of the sinus—small, straight, long strips of gauze having nothing in common with the methodical plugging of a widely open bony cavity to ensure its healing from the bottom. The small strip introduced by a probe scarcely dilates the track,

does sometimes reach as far as the bone, but never enters the cavity itself. The day when on removing the strip in order to change it a small sequestrum is found at its end, great joy is experienced and great hopes indulged in; but the sinus goes on as before, becoming neither smaller nor larger. Where there are any deep sequestra enclosed by sub-periosteal bone formation, this is a useless and deceptive method of treatment. And where there are none but merely a limited area of bare bone, it is harmful; the introduction of the foreign substance merely keeps up the suppurating track, just as in former days the issue peas kept up the ulceration produced by the cautery or the tent kept open the seton. When I see a patient with a chronic sinus with but little discharge, in whom the bone is neither enlarged nor tender, nor shows on skiagraphy any area of rarefaction, the first thing I do is to order the removal of the gauze drain, and in more cases than might be expected I see sinuses that have been kept discharging for months heal in a few days.

An official circular—which I published in the *Bulletin de la Société de Chirurgie* in April 1915—recommended the soaking of the gauze drain with a polyvalent serum obtained by MM. Leclainche and Vallée by immunising horses against aerobic and anaerobic bacilli of various sorts (staphylococcus, streptococcus, bacillus coli communis, bacillus pyocyaneus, bacillus perfringens, etc.); and a writer whose name I prefer not to mention, although Roux has presented him to the "Académie des Sciences," has affirmed that by this means excellent results have been obtained *without danger*, that the serum at first quickly produces signs of acute inflammation and the

suppuration appears to be increased, but that as a matter of fact the sinus discharges an abundant leucocytic exudate instead of pus, sequestra and foreign bodies are mobilised, the gauze becomes entangled with them, and they come out with it or else are easily removed with forceps, the result being usually a rapid cure.

On *a priori* grounds these statements would appear strange to surgeons who know exactly what an enclosed sequestrum and a bony cavity mean. Judging by results—a point of view which is of greater value—I have seen patients thus treated who have had later in order to be cured to submit to an extensive operation, and, above all, Mouchet has supplied us with certain details which the writer had thought fit to omit from his circular.

1. The reopening of sinuses amongst the wounded, who have been discharged as healed, is frequent: the time that has elapsed before reopening of the sinus has often been no longer than that of the journey from Beaugency to Orleans, which did not take very long even in D'Artagnan's time.

2. Lymphangitis and even erysipelas have occurred in almost 50 per cent. of the cases.

3. Very often the suppuration has been profuse and foul, with sloughing of the wall of the sinus. What takes place in the soft parts also takes place in the bone, where necrosis of the superficial parts or caries in the epiphyses occurs to a much greater extent than before, and even sometimes provokes a suppurative arthritis.

4. All this does not happen without a serious affection of the patient's general condition—a septicæmia that may even prove fatal: and certain deaths

are accompanied by clinical signs that point to a poisoning of the bulbar centres.

It is unfortunate that the results have not realised the hopes of the inventors and the assertions of the practitioner who used it, for it would have been, as Delbet said, " excellently polyvalent." And also, as I remarked to Delbet, the list of bacteria against which it is effective, although already long and varied, ends with " etcetera," in the same way that the heathen, in order to propitiate all the divinities, raise their altars to " The unknown God."

These unfortunate occurrences are due to irresponsible and incompetent scribblers—although, perhaps, medical men—for the serum of Leclainche and Vallée seems to be remarkably efficacious in preventing gas gangrene, as these workers had shown even before the war. It is a pity that the work of two such eminent scientists should have been thus compromised.

Physiotherapy has of course had pretensions as regards the cases we are now dealing with. I set aside for the moment manipulations, massage, methods which have rightly or wrongly been used in the treatment of the atrophy of muscles, the stiffness and deformity of joints associated with compound fractures. I shall deal later with the indications, and also with the frequent disadvantages of this form of treatment whilst there exists an open sinus or even a mass of exuberant callus, the possible origin of a recrudescence of inflammation. But the one constant objection that has developed during the last ten years against physiotherapy is that its practitioners seem determined to find agents suitable to the treatment of chronic sinus as a disease in itself. I have seen

patients with chronic sinuses without joint disability sent to these centres for treatment by physical agents.

It is especially to sunlight that physiotherapists have turned, believing that its action could lead to the expulsion of sequestra, and thus to final healing. Instead of the sun, some have employed radiant heat. I know that heliotherapy is fashionable at present, and that to doubt its universal power is to court unpopularity. I had, however, doubts about it before the war, and I have them still. Exposure to sunlight and to radiant heat are excellent means of treating certain chronic wounds and certain ulcers with a thin serous discharge. Heliotherapy in the case of a tuberculous sinus of a bone or joint origin often results in a decrease of the chronic inflammatory infiltration of the soft parts, which are thereby rendered more supple, and in a rapid healing of superficial sinuses. It seems to me to have a real sterilising action on the mixed pyogenic infection, which at this stage is so often a serious complication. But it certainly seems to be absolutely incapable of eliminating sequestra, tuberculous or otherwise, or of closing up an osteomyelitic cavity. We all know the phenomenon of spontaneous discharge of sequestra from a cavity, and understand the anatomical conditions that render it possible; no one has proved that it is any more frequent after heliotherapy.

It was traditional in the older treatises to claim a peculiar virtue for mineral waters in the cure of bony sinuses, and naturally the modern prospectuses of these establishments still maintain this claim. Amelie-les-Bains is the principal military centre for balneological treatment, which seems to have a certain range of usefulness in stimulating slow-healing wounds, but

which it is most certain is quite useless if there be sequestra, or even a bone cavity without sequestra. Granted that it might be useful to try this treatment when a granulating surface persists and refuses to heal, *e.g.* a large gutter cavity in the tibia, still I must add that in my own practice of civil as well as of war surgery I have not yet found it necessary in any case.

As a matter of fact, all these auxiliary means are contra-indicated when there are sequestra or cavities in the bone. The only treatment that should be advised is operative. The operation will be a simple one, followed by a rapid cure if the sequestrum is superficial and leaves no cavity in the bone behind it but a small and unimportant one, and in this case the cure will be much more rapid than by those non-surgical methods that are supposed sometimes to have contributed to the spontaneous expulsion of the dead fragments. The operation will be difficult, complicated, and the final healing delayed if there are sequestra buried deep in the bone, which leave behind a large cavity with thick walls; but in a case like this all the other methods, although one may have been inclined to believe in them, would have been perfectly useless.

When a sequestrum has come out spontaneously, or what I repeat appears to me to be the same thing—after-treatment by one of these agents—it should be possible to judge from the size of the bone or from the appearance of an X-ray plate (remembering, however, the reservations that I have made in this connection) whether there is any chance of its having been single and superficial, in which case the healing up of the soft parts should take but a few days. But

these spontaneous eliminations of small fragments are almost always of no curative significance—large pieces still remain inside the bone—and even supposing that these too could be discharged in the same way, there still remains the pathological condition of a sequestral cavity which, if even of only moderate size, will never spontaneously fill up and heal. This at once brings us to the realisation of the fact that the operation which should be performed is scarcely ever a mere scraping or curetting. These are words that have become popular and of common use to such an unfortunate extent that they are apt to make one think that they refer to an easy, slight operation, the performance of which lies within the capacity of anyone, that consists merely of enlarging the sinus and scraping with a sharp spoon the opening in the bone.

It was a great mistake among those who, in peace time, prepared for war surgery, and even among those who directed it during the first few months of this war, to have neglected the lessons of the past, and to have imagined that because of " humane " projectiles and of antiseptics late inflammatory phenomena in compound fractures would not occur, or at least would be of but little importance. Hence the attention given to the treatment of sinuses was too often far from sufficient—a gauze drain in the sinus, at intervals a scraping with a sharp spoon, sometimes performed even without an anæsthetic.

I am not even sure that certain professional surgeons, disdainful of what does not concern the visceral cavities of the body, have always been well versed in the details of the pathology and surgical treatment of traumatic osteomyelitis. They know

all about intussusception and the importance of operating on it, but often they seem to think that the mere removal of sequestra is sufficient—an idea that is essentially wrong.

Certainly we should before all things remove sequestra ; this alone suffices if the cavity left is small and the sequestrum has been superficial. But in the great majority of cases this alone is quite insufficient, the cavity in the bone still continues to suppurate. What is required is a surgical procedure that will obliterate this cavity once for all. The necessity for the removal of enclosed sequestra by enlarging to the necessary extent natural openings in the walls of the cavity—cloacæ—or by actually cutting away sufficient of the wall itself, will be readily understood after what we have said regarding the pathological anatomy of chronic osteomyelitis. As to the treatment of the cavity itself, various methods are in use. It will be necessary to explain the principles of these, and to point out the details of their application.

Under the influence of the pioneer researches of Ollier free sub-periosteal resection of bones has been performed, especially in the osteomyelitis of childhood. The periosteal cylinder if preserved was to lead to regeneration of the bone. This osteogenesis, however, proved less invariable than had been supposed even in childhood, still less so in the adult, hence this practice has little by little been given up.

Sédillot was quite right when he fought against Ollier for the mere excavation of diseased bone as opposed to the complete resection of bone in chronic osteomyelitis. We can no longer now collect those museum specimens which were so interesting at the time when they were obtained, in which the whole

former shaft is seen lying as a sequestrum inside a case of new sub-periosteal bone. Sédillot was in the right in holding that it would have been far better had Larghi and Borelli merely removed the sequestra, rather than have practised total sub-periosteal resection for deep necrosis ; he was certainly in the right to maintain the greater field of usefulness of the more limited operation. It is enough to read Ollier's *Traité des Resections* to be convinced that little by little, for the extra-articular lesions considered here, the Lyons master was not long before he himself came to follow the path on which we are to-day. If he insisted on the rôle of the periosteum, he also ventured on studies from which to-day we have to borrow in connection with the healing of bony cavities with rigid walls. Let us consider any abscess of the soft parts, let us take, for example, a case where the abscess is kept up by the presence in it of a foreign body ; when this is removed at once the soft parts subside, the walls of the abscess come into contact, and healing of the cavity soon takes place. On the other hand, clean out as carefully as you like an abscess cavity with rigid walls, and it will heal only with its complete obliteration. This can be brought about in one of only two possible ways :—

Either it fills spontaneously by the abundant proliferation of granulations from its walls ;

Or it becomes filled by the entrance of neighbouring soft parts into it.

*The Spontaneous Ossification of the Cavity.*—" The radical operation in osteomyelitis," says Sédillot, " is one that by excavation of the bone completely removes all diseased areas and leaves only the healthy cortical or peripheral sub-periosteal layer of the bone.

By it the shape of the limb remains unaltered, muscular attachments to bone are spared, the periosteum is left intact, and formation of new bone takes place both from the deep surface of the periosteum and from the walls of the excavated cavity."

Where the bone that remains is healthy, this production of new bone is closely analogous to the process of repair in fractured bone, that is to say, the cavity fills with blood-clot, which, gradually replaced by mixed tissue elements arising by proliferation of the essential marrow cells alike of sub-periosteal and cancellous bone and of the medullary canal, ultimately becomes converted into bone, after having passed through an intermediate stage of conversion into cartilage.

In an experimental excavation involving, after careful elevation and preservation of the periosteum, merely the underlying layer of compact bone, very little blood is effused; this on clotting becomes rapidly absorbed, and the periosteum, sinking down into the cavity, soon becomes adherent, and only later from its deep surface deposits new bone. Hence no matter how shallow the original cavity has been, there always remains a depression in the bone to mark the place where the experiment has been made; in other words, the regeneration of the compact bone has not been complete.

Similar experiments have been carried out during the last fifty years by many different workers with the object of studying the repair of solutions of continuity artificially produced by saw-cuts in compact diaphysis or in cancellous bone, sometimes involving only the superficial layers, sometimes penetrating deep into the medullary cavity, in certain

cases accompanied by careful preservation of the periosteum, in others by more or less extensive removal of it. All such experiments have served to demonstrate the osteogenetic properties of granulations arising alike from the deep surface of the periosteum, from the Haversian canal systems, and from the medullary canal. I am not going to insist specially on this property, to-day universally recognised, of the sub-periosteal layer, nor to concern myself with the theoretical discussion as to whether this layer really forms the deep layer of the periosteum or the most superficial layer of the bone. The practical fact is sufficient for us that when the periosteum is stripped, pathologically or by surgical means, this layer follows the fortunes of the periosteum. I will remark in passing, however, that it is largely this new bone of sub-periosteal origin with which we are concerned in the performance of this operation for the cure of osteomyelitis; it is sub-periosteal new bone that requires removal, that is found enclosing the sequestra formed by the necrosis of the original shaft, that forms the walls of the cavities and tunnels full of pus and granulations that require excavation and obliteration, so that in such cases the whole process of repair of the bone lesion is due almost entirely to the activity of this layer.

These experiments have given results which do not differ from those which were carried out by Ollier himself, and formed the starting-point of all our knowledge of the process of repair of bone.

The results, thanks to the discovery of antisepsis and later of asepsis, have been improved, but only in the direction of greater frequency of success, and because we can now eliminate the results of infection of the experimental wound. This is specially true

as regards the aseptic organisation of the effused blood-clot, to-day so well known; further on we shall see what surgical inferences can be drawn from this.

This organisation of clot, the importance of which—in the repair of compound but uninfected fractures—was long ago proved by Lister, results experimentally in the complete filling up of small bony cavities produced by excavation, over which immediate suture of the periosteum and soft parts has been carried out. In the course of a few weeks the bone, the solidity of which has not been interfered with, returns almost completely to its former state, only a small depression remaining to show the site of the operation. A similar result follows the cutting of a straight groove along the long axis of the bone. Blood fills the cavity left by the operation, forms a matrix which is replaced by granulations that become fibrous, then cartilaginous, and then finally ossify.

Such granulation tissue besides possesses a certain power of contraction which, by drawing the walls of the cavity towards its centre, diminishes to some extent the size of the cavity. This is of little practical significance except in special cases, as in the obliteration of a cavity in the jaw after extraction of a tooth. In this case, however, there comes into effect an important absorption of the walls of the cavity that allows of the collapse of the neighbouring soft parts. But in real surgical cases such an absorption of the walls is absent or is insignificant. It is true that Sédillot in the early stages of his research believed that such took place in the thinned-out sub-periosteal layers of the bone, leading to an increase in the elasticity of the walls that resulted in a concentric decrease in the size

of the cavity ; at the same time he considered that the periosteum was partly drawn inwards by retraction of the granulations in the cavity, partly pressed in by the weight and tension of the overlying soft parts. Perhaps Ollier was wrong when he denied absolutely the existence of such processes, but he was right in the sense that the surgeon has no right to depend on their occurrence.

The practical fact remains that if a cavity of some size has been excavated in a bone, the rigidity of its walls is such as to render all possibility of their collapse quite negligible ; and as, on the other hand, the ossification of the granulations from within is always an exceedingly slow process, complete repair of the cavity becomes most difficult of realisation. The greater the size of the cavity the more difficult does this repair become ; indeed it increases not in arithmetical but in geometrical progression according to Ollier, but one can hardly, in this connection, give their real mathematical value to these words.

In the repair of such cavities, as in all questions of bone surgery, the age and state of the general health of the patient are of great importance ; the younger the patient, the more chance is there of spontaneous ossification, and in the case of children one would attempt conservative measures which one would not dream of considering in the case of adults.

Some writers have attempted to transfer these physiological principles to the realms of surgery, and to apply them in the treatment of bone cavities of large size ; they just apply a tourniquet and excavate the focus of disease ; the soft parts are then closed by suture and the tourniquet released, so that the cavity fills with blood. The clot will become organised and

serve as a basis—gradually undergoing absorption the while—for a real *osteogenesis by substitution.*

This is most brilliant surgery, but it demands an absolute asepsis. Now *the complete disinfection of such a cavity in osteomyelitis is quite impossible,* and all attempts to obtain this ideal result by this method have failed. I am not ignorant that Bier has described an osteoplastic removal of sequestra in superficial bones like the tibia, which is an extreme example of this type of operation, and for which he makes great claims. Two transverse incisions going right down to the subcutaneous surface of the bone and extending a little further outwards than the crest of the tibia are made corresponding to the upper and lower limits of the diseased area ; a third vertical incision is then traced, joining the inner ends of these two transverse incisions. Along these three sides of the rectangle so formed the bone is divided from without inwards ; the chisel is next inserted into the vertical cleft in the bone, and with it the outer surface of the shaft divided from within outwards, the periosteum over this surface, however, being respected. In this way a large osteoplastic flap is cut of the shape of the lid of a snuff-box, which is then levered up from within outwards ; after the sequestra have been removed and the sequestral cavity cleaned out, this flap is replaced into its original position, no drainage being used.

I have never tried this method, and I shall be surprised if ever I come to do so, for it has always seemed to be most irrational to leave blood-clot thus enclosed in an inevitably infected dead space. I think that if its author has employed it he can have declared himself satisfied with it only by viewing the results obtained in too favourable a light.

Attempts have been made to render the cavity aseptic by *packing it with antiseptics prior to allowing it to fill with blood-clot.* In turn powdered iodoform, iodoform-glycerine emulsion, the subnitrate of bismuth, and salicylic acid have been recommended. The results have not been good; apart from the occurrence of cases of iodoform poisoning, it did not take long to prove how unreliable and uncertain chemical agents are in rendering aseptic an already infected field of operation. This fact, which holds good for all operations, applies especially to where a rigid incompressible cavity is left in which blood-clot mixes with the antiseptic and forms so important a part of the obliterating mass.

Since the attainment of absolute asepsis remains thus uncertain whatever antiseptic be used, the less blood allowed to accumulate in the cavity the better. It is on this account that most processes of "substitution" aim either at packing the cavity as tight as possible, or at filling it with substances that by accommodating themselves absolutely to the irregular shape of the cavity succeed in its temporary complete obliteration.

### A. Methods in which the Cavity is packed with Organic Materials

Whatever substance is employed, it is quite evident that blood will fill in the interstices; but also it is evident that this blood may be reduced to a very small quantity, merely thin layers, which on coagulation serve to unite the bone to the foreign substance. The substances used are of an organic nature, but absorbable. They are divisible into two classes:—

1. Sponges and various organic substances other than bone.
2. Dead bone, decalcified or not.

### 1. *Sponges and Non-bony Organic Substances*

We will take the packing with sponges as the type of this method of treatment, because it was the first recommended, and because under the very bad name of sponge-grafting it has been used in exact experimental work as well as therapeutically.

In the original technique of Hamilton (1881) Turkish sponges were used; they were cut into thin slices, decalcified by immersion in weak hydrochloric acid, washed in an ammoniacal solution, and kept in 1 in 20 carbolic acid. The practice of Duplay and Cazin, who allowed the sponge to retain some of its siliceous spicules, is of no particular interest. The only really important or vital point was to assure the absolute asepsis of the sponge, and for this one had to trust to prolonged immersion in antiseptics. With Hamilton's technique failures were frequent, and the only certain method of assuring the absolute asepsis of the sponges is to cut them into variously shaped fragments and submit them for half an hour to a temperature of 120° C. in an autoclave. This makes them a little gelatinous, but this is rather an advantage than otherwise. This extraneous substance having thus been rendered aseptic, all will go well if the cavity into which it is packed is also aseptic—a condition easy to realise experimentally. After a first, but temporary, very tight packing in order to stop hæmorrhage, the final packing is carried out less firmly, so that when the sponges swell the cavity will not be

over-distended; the periosteum and then the soft parts are closed by suture.

In experiments on the rabbit, by the fifth day the fragments of sponge were so firmly united to one another and to the bony walls that a cross-section of the cavity with a saw failed to displace any of the fragments, and in such a cross-section the respective limits of sponge and bone were no longer to be distinguished. By the fiftieth day sponge was no longer to be detected by the naked eye, and bony repair had proceeded at a rate far greater than in the control animals in which the bony cavities had been left empty.

Under the microscope an intense proliferation of cellular elements was seen to occur; from the fifth day onwards these invaded the interstices of the spongy network, and little by little replaced it. This latter became absorbed, whereas the newly formed granulation tissue became ossified, and by the time repair was complete there remained in the new foundation of bone only some few spicules of silica of no practical importance to remind one of the previous presence of the sponge.

Other organic materials have been used by various workers, and the results of each have been compared with that obtained with sponge by Duplay and Cazin. Iodoform and aseptic gauze give very similar results; silk and cotton are not so easily penetrated by the proliferating cell elements, and cotton even becomes encased by fibrous tissue; aseptic catgut is also less easily penetrated but more easily absorbed than sponge, but its greatest defect is the uncertainty of its sterility. It is unnecessary to do more than mention such substances as muscular fibres of the calf, the sub-mucous

coat of the pig's intestine (Halsted), filaments of fibrine of bullock's blood treated with corrosive sublimate, iodoform in alcohol, or ether—substances all of which being difficult to prepare and to sterilise with any certainty, possess besides no counterbalancing advantages over the previously described materials, and none of them have gained any permanent place in surgical practice.

### 2. *Dead or Decalcified Bone*

When the insertion of these substances, absorbable and favourable to osteogenesis by substitution, was first thought of, special attention was paid to the use of fragments of bone, as it was considered on theoretical grounds, which, however, turned out in practice to be quite untrue, that the Haversian canal system of bone would prove a useful path already prepared for penetration by the elements of the future new bone, that the already existent structure of the bone would thus be specially favourable to the building up of new bone tissue.

In 1889 Senn thought of decalcifying the bone to make it more malleable and more easily cut into pieces, whilst still preserving its supposedly advantageous canalicular structure.

The bone intended for decalcification is taken from the compact portions of the tibial or femoral shafts of the bullock. The hard bony tissue alone is used, the periosteum and marrow being removed; it is cut up into small chips or else into much larger fragments, according as one is going to make use of one or other of two different methods of implantation. These pieces are then placed in a 1 in 10 solution of hydro-

chloric acid, which should be changed every day. An eight days' immersion will produce sufficient decalcification, but for the completion of this process about four weeks is necessary.

The bone is now soft and easily cut. It is washed in plenty of water to remove all excess of acid, or else immersed in a 1 in 500 aqueous solution of corrosive sublimate. It is kept either in weak potash solution, then for forty-eight hours in 1 in 500 aqueous solution of sublimate, or else in iodoformed ether (1 in 10).

Before being used the decalcified fragments are wiped dry, then plunged for a short time into alcohol, then into an aqueous solution of sublimate 1 in 2000, or in 1 in 50 carbolic acid, and finally they should be dried with the greatest care so as to render them absolutely free from the least trace of alcohol, in the presence of which they would swell when packed into the bony cavity with a force sufficient to burst the stitches.

The excavated cavity is prepared for the reception of the decalcified bone chips by the most careful removal of all dead or diseased bone ; it is then wiped clean, thoroughly flushed out, and sprinkled with iodoform ; efficient and complete hæmostasis will have been provided for by the preliminary application of an Esmarch's bandage. When it is quite dry the bone implantation is carried out, the chips being inserted and pressed down so as to leave no dead spaces.

The wound is closed without drainage. The first dressing should not take place until the 12th or 14th day, and after that only at the end of two or three weeks if primary union has occurred, sooner, and as often as necessary, if there has been suppuration.

When this is profuse it will probably be necessary to remove the stitches and also the bone packing, the case thus resulting in failure ; another attempt may be made later when the discharge has again ceased.

The process of repair in successful cases has been studied in the rabbit and in the dog by Ochotin and by Buscarlet. Placed in the cavity and surrounded by a capsule, the decalcified bone first produces inflammation of the bony walls, whose essential elements proliferate and soon commence to eat into the decalcified bone—a process that takes place to a greater extent from the medullary than from the periosteal wall of the cavity. This is indeed almost the same process as occurs in the case of a living bone graft that has " taken," except that in this latter case a definite circulation is established in the graft which, until the time of its reabsorption, causes it to take a definite place in the life of the tissues.

Absorption of decalcified bone takes place sooner than does that of dead bone or of living graft. It is even said that it takes place so rapidly that the final result is merely a fibrous and not a bony cicatrix, but it is easy by decreasing the length of time of its initial immersion in hydrochloric acid to render the process of absorption less rapid.

In the hands of Senn and of his pupil Mackie good results have followed the employment of his technique, especially in the case of cavities as large as hazel-nuts or walnuts, but these are too small to convince one of the practical utility of the method.

In other hands most attempts have failed. Buscarlet, with his master Le Dentu, however, considers that it is of some advantage in cases of large cavities, over which it allows the suturing—instead of packing

—of the soft parts, so that in young people the period of healing is shortened.

This temporary support is of no use, however, if the patient is old or if the periosteum has been sacrificed, but in most excavated cavities it is preferable to the use of living bone. This latter, on the other hand, is of more use in the restoration of a whole bone, when the provisional support for the ultimate ossification must last for a long period.

Incompletely decalcified bone has the advantage of being more slowly absorbed than a massive graft; also, it brings to the centre of active repair calcareous material necessary for the process.

The difficulty of preparation and sterilisation of the substances to be implanted, the almost inevitable persistence of unoccupied dead space in which blood accumulates, are the inconveniences of the method.

In place of decalcified bone, Barth has proposed to fill the cavity with the ashes of incinerated bone, Grosse with a mineral powder (phosphate of lime 85·6, phosphate of magnesium 1·75, chloride of lime 3·5, carbonate of lime 9), on the theoretical ground of furnishing elements necessary to the building up of new bone. All these have merely resulted in persistent suppuration, with the ultimate discharge or removal of the implanted substances.

### B. Methods in which the Cavity is filled with Emulsions and Pastes of an Inorganic Nature [1]

These methods are the only ones that allow of absolute obliteration of all dead space in the cavity,

[1] This procedure is commonly called "bone stopping or filling." The only real bone filling consists in securing (as in dentistry) the complete

the substance used fitting closely to the walls of the cavity during their application; all hæmorrhage into the cavity must be prevented by the use of Esmarch's bandage. Such substances as have been used are aseptic, or so mildly antiseptic as to overcome as far as possible the existing infection of the bone, but at the same time avoid compromising the vitality of the osteoplastic elements.

I pass in silence over pastes of plaster, cement, etc., and commence at once with the antiseptic mixtures that set to a solid. Under the name of *iodoform paste* they have been much in evidence during the last twenty years, although perhaps their usefulness has been over-estimated.

In 1896 P. Reynier and Isch-Wall, in order to avoid reinfection of the blood-clot, recommended pouring into the bone cavity an antiseptic that would set to a solid—*salol iodoformé*. Salol melts at a temperature slightly greater than blood-heat, and in its melted form it becomes capable of dissolving iodoform; at 98·6° F. the mixture solidifies into a vitreous mass. The melting point of the mixture is sufficiently low to allow of its being poured in the liquid state into the cavity, and on its solidification at body temperature the smallest irregularities of walls of the cavity become obliterated. The cavity should be first prepared successively with iodoformed ether, chloride of zinc, and the thermo-cautery—the antiseptic power of the iodoform and salol mixture is expected to destroy any remaining bacteria;

obliteration of a bone cavity with a malleable foreign body (originally lead, then various metals, then non-metallic bodies) destined not to be absorbed, but to become encysted. This has been done in long bones with various substances (copper amalgam, lead, gutta-percha, cement). In osteomyelitis, failure is invariable.

complete closure of the soft parts should then be performed. It should be added that the size of the cavity should not exceed that of a nut.

It is sufficient to mention attempts made with such substances as naphthalene, a formalin-gelatine mixture, and of paraffin.

The antiseptic mixture invented by Neuber is a real paste, having the following composition: 10 grams of flour are soaked in a little cold distilled water; whilst this is being stirred 200 grams of a boiling solution (12 in 100) of carbolic acid and then 10 grams of powdered iodoform should be added. This iodoform paste is poured into the cavity after it has been thoroughly dried out, and the soft parts then sutured. The tourniquet should then be removed, and blood becomes mixed with the paste; healing by first intention occurs in two-thirds of the cases. Before filling up the cavity it is necessary to change all instruments, swabs and towels, etc., that have been used up to this stage of the operation: the surgeon and his assistants should also resterilise their hands. The observance of this technique is absolutely necessary if reinfection of the cavity is to be avoided. The soft parts on being sutured should not be subjected to any tension. Since this method results in a considerable intermixture of blood with the obliterating medium, it really forms an intermediate between the method of Schede and those in which are used real pastes made of substances that become quite solid.

Since 1898 Mosetig Moorhof has studied the action of an *iodoform paste* which he has made famous. It is intended to obliterate the cavity completely, and to be itself subsequently absorbed; hence it comes

into the category of substitution processes. The formula of Mosetig Moorhof is as follows :—

| | |
|---|---|
| Powdered iodoform . . | 60 grams. |
| Oil of sesame . . . | 40 ,, |
| Spermaceti . . . | 40 |

Equal parts of the last two constituents are melted on a water-bath in a cylindrical glass vessel ; this results in a clear oily liquid, which must now be filtered. The powdered iodoform is then added and well stirred in, and when the whole is of a uniformly yellow colour it is removed from the fire. During cooling up to the stage of consolidation it should still be kept stirred ; solidification takes place between 45° and 50° C., and the glass vessel containing it should then be covered with a sterile lid. It should again be melted on the water-bath just before use, and arrangements should be made that the outside of the glass container should be sterile, so that the surgeon can take it and pour the liquid from it directly into the bone cavity. Warmed thus on a water-bath it is not hot enough to damage the walls, to which on solidification it accommodates itself absolutely.

Careful preparation of the cavity is of the utmost importance ; it is quite useless—although almost a classic routine—merely to scrape with a spoon and then to pour in oil or glycerine that is then evaporated *in situ* by the application of the thermo-cautery. For the four days preceding the operation the skin should have been regularly disinfected by the liberal use of soap and water, alcohol, and ether, and by constantly applied wet antiseptic fomentations. The bone is approached by incisions through healthy skin,

the cavity is opened for the removal of sequestra, and then with the chisel, or better with a burr, all the diseased or suspicious parts are excavated. One should stop short only when well into healthy bone.

The cavity should be perfectly dry, so that the mixture can adhere everywhere to the walls quite perfectly, hence the necessity for the use of the tourniquet wherever possible; even with it absolute hæmostasis in the cavity is often difficult to obtain. After having irrigated the cavity with 1 in 100 formalin solution so as to wash away the bone dust and débris produced by the burr, the cavity should be swabbed out as dry as possible, small points exuding blood being touched with adrenalin or oxygenated water, the preparation ending with the thorough drying of the cavity by means of currents of cold and hot air. If the use of a tourniquet is impossible, as in the shoulder and about the hip, the complete and necessary hæmostasis of the cavity will be a process that will test the surgeon's patience.

Into the cavity thus prepared the liquid should be poured a little at a time, the position of the limb being constantly changed so that every crevice and recess is completely filled. Solidification should be allowed to occur spontaneously, no attempts being made to cool it rapidly by ice or ether vapour. Only in the neighbourhood of joints is drainage necessary; in other cases the remains of the sinuses which have been carefully excised early in the operation suffice for drainage.

The various layers of tissue are then sewn over the cavity, including the periosteum, which on first approaching the bone should have been carefully elevated and preserved. After completion of the

dressing and fairly firm bandaging of the limb the tourniquet is released.

Mosetig Moorhof is very much against performing the operation in two stages, the filling of the cavity being delayed some days until its walls are granulating. He considers the attainment of absolute asepsis impossible under such circumstances, and that the paste should be used either in the first instance or not at all.

The first dressing should be performed on the tenth day; in cases in the lower limb the patient should be able to walk naturally in six weeks. If immediate healing is obtained, the iodoform mixture becomes gradually absorbed; if, however, suppuration occurs, more or less of the mixture is gradually extruded through the incision or through the openings of former sinuses; but it should not be squeezed out, much less deliberately removed. Histologically the process of substitution of this mixture is very similar to that we have described as obtaining in the other methods and procedures. Successive radiograms allow one to follow the progress of the absorption and ossification; but it must be confessed that on account of the relative opacity of iodoform to the X-rays, it is not always easy to be certain of the exact limits of the latter process.

On account of the fear of iodoform poisoning it has been proposed to replace the iodoform by some other antiseptic—Mosetig Moorhof himself experimented in this direction; but the other antiseptics used were found to give less satisfactory results, and as with his formula no case of poisoning had been known to occur, he concluded that such an alteration of composition was not justified.

Mosetig Moorhof was delighted with the results of his method; these were published by his pupil Damianos in 1904, and by himself in 1906. Up to this latter date he stated that he had in five years operated on more than 1000 cases with uniformly good results. This implies a truly extraordinary operative activity, since even in our largest special surgical clinics for children we meet with but few cases of large bone cavities requiring operation, and it is with such cavities only that we are concerned. As to the late results of his operation the writers gave no account, a fact that did not deter Rottenstein, however, from attempting to introduce the method into France. For, he argued, of the cases published in 1904 a good number dated back to 1899; if there had been cases of relapse, these would not have failed to return for further treatment. Mosetig would have operated again on these, and an account of such would have appeared in his tables of statistics; none such did appear, hence there could have been no relapses. I give this argument for what it is worth, but I confess it does not persuade me.

Again, according to Rottenstein, Mosetig Moorhof's results were very different from those of his followers, whose cases sometimes developed abscesses and sinuses, which Moorhof's never did. This he attributed to imperfect technique, especially to imperfect drying of the cavity.

A paste proposed by Fantino and Valan has the following composition :—

| | |
|---|---|
| Thymol . . . . . | 1 |
| Iodoform . . . . . | 2 |
| Calcined bone ash . . . | 3 |

These writers advise a two-stage operation: first, to excavate the cavity, which is then scalded by evaporating a glycerine-iodoform emulsion *in situ* by means of the actual cautery; four days later, after a bacteriological examination of the discharge from the cavity which has been packed with aseptic gauze has proved its sterility, the cavity is filled with this paste. Especially successful in cancellous bone, this method yielded eight successes out of nine cases, small cavities being cured in three months, the large ones in seven or eight.

A eugenol paste has been used by Joüon (of Nantes), who has published his results.

Eugenol is an oily fluid, strongly antiseptic, and slightly analgesic, the active principle of the oil of cloves. Mixed with zinc oxide, it forms a paste which sets rapidly into a mass as hard as marble. This requires to be prepared actually during the operation, the eugenol being poured drop by drop on to the zinc oxide, previously finely powdered and sterilised by heating to 120° C. spread out on a plate. The paste must be kept continually worked up until it will no longer stick to the skin, when it should be kneaded into the cavity, working it in all the time so as to keep it homogeneous with a special instrument something like a burnishing tool. The cavity, which has been thoroughly excavated, is sterilised by touching its walls with pieces of gauze soaked in a saturated solution of carbolic acid in glycerine; absolute dryness and hæmostasis are indispensable conditions for perfect adhesion between the mortar and the bone walls. This substance does not become encysted by fibrous tissue, but is gradually absorbed and replaced by bone.

*Delbet's mixture* has the advantage of being capable of previous preparation. Its composition is as follows :—

| | |
|---|---|
| Pure wax . . . . | 50 grams. |
| Chloroform . . . | 6 c.cm. |
| Tincture of iodine . . | 6 ,, |

The wax is melted on a water-bath, and then poured into a flask previously warmed to prevent too rapid solidification ; the chloroform and tincture of iodine are added, and the flask tightly stoppered, and then shaken until its contents have become completely solid. (During this process the cork must be kept tightly in place, otherwise the chloroform vapour will dislodge it.)

This paste is malleable ; at ordinary temperatures it is easy to mould to the walls of the cavity, to which it adheres despite oozing of blood, and it acts directly on them as a hæmostatic. It seems to be the best of all for aseptic cavities, but Delbet soon gave up using it in osteomyelitic cavities, and at this I am not at all surprised.

As a matter of fact I have given careful attention for several years to every publication that has appeared on the treatment of chronic osteomyelitis by such means, with the practical result that I do not myself have recourse to them. In practically all cases (and even, I should add, when used in primarily aseptic cases) late suppuration occurs and the formation of chronic sinuses with ultimate discharge of the paste. Many cases have been reported in which a sinus persisted, very small perhaps, but such a statement does not mean much.

It has often been claimed that, although the results

of these methods have disappointed our hopes of securing primary union and aseptic absorption, these substances nevertheless constitute an excellent "internal dressing" which facilitates and hastens ultimate cure. Even this very modest claim is, however, not incontestable. From my study of numerous reports and observations I have received the impression that the effect of this "internal dressing," both upon the duration of healing and the ultimate cure, is exceedingly doubtful. Most cases of osteomyelitis of subcutaneous bones like the tibia, that are comparatively easy of approach, are cured by these methods, under conditions, however, that seem to be identical with those that obtain in the method I am going to describe. Similarly in extensive osteomyelitis of deep lying bones, of the lower end of the femur in particular, failures are common equally with the two methods.

The impressions that I had received before the war have not been modified in any way since. These methods of "filling" the cavity with pastes and cements, etc., have been frequently tried, but they have proved of doubtful value. I am not speaking of the failures that have come later into my charge; I should be told, of course, that naturally no one would send me the cases they have cured. But I am almost certain that cases of primary union without the extrusion of the extraneous matter have been quite exceptional, and that when such extrusion has occurred the mixture has done no good whatever.

### C. The Technique of the Operation for the Obliteration of Cavities and Tunnels in Bone

I have always practised a wide removal of bone with free resection of one of the walls of the cavity, thus allowing collapse of the neighbouring soft parts, periosteum and muscles, into as complete and close contact as possible with the remaining bony wall; and it is the technique of this operation that I am goint to describe.

I never use a tourniquet in these cases.

1. The bone should be approached by a free longitudinal incision. This should be of such a length as to extend both up and down considerably beyond the limits of the bony cavity as proved previously by radiography; if need be this incision should be enlarged to conform to this rule during the course of the operation. Every bone has its "surgical" surface, over which one should incise the soft parts in order to approach it; no special attempt should be made, in planning the incision, to include in it the opening of one or more of the sinuses. Indeed the fistulous opening should form part of the incision only when it happens to coincide with the ideal site for incision that I shall describe later on; to attack a tibia, for example, from the back because the sinus opens there would be absurd.

The skin will often be found very tightly adherent to the bone, the muscles usually atrophied, discoloured, and fibrous; the periosteum, which will be greatly thickened, should be split from end to end of the incision. Then with the rugine the two lips of this should be raised and held aside with retractors so as to expose a third or even a half of this sur-

face of the bone, which will then appear rough and vascular.

This surface of the bone is sometimes soft and easily cut through with the curette; sometimes, and more often, hard and compact. Particularly is this the rule around a "cloaca," especially where this has been the result of a previous operation; here the new sub-periosteal bone is densely hard and eburnated; a sharp spoon will make no impression on it.

2. Hence mallet and osteotome are nearly always necessary in the second stage of the operation, which consists in opening up a large groove or furrow in the bone (nearly always newly formed of sub-periosteal origin) in order to get well inside the cavity that contains or has contained the sequestra. If an already existing opening presents, commence with this, chiselling so as, guided by the probe, to follow and open up the whole main cavity and its various prolongations.

If, however, there be no cloacæ presenting in the field of operation, then the bone must be chiselled in a direction parallel to the incision, first along the right side of its exposed surface, and then along the left; the upper and lower limits of the rectangular surface of bone that lies exposed must then be likewise cut through; the operator should first perform the upper—which is also the easier—of these divisions of the bone.

An experienced surgeon will know at once by the peculiar sound produced and by the sensation imparted to his hands exactly when the chisel enters the cavity in the bone; when the cavity has thus been opened from both sides, the surgeon, using the chisel as a lever, elevates *en masse* the whole wall of bone between the four lines of division.

The exact limits and size of the cavity that will require thorough excavation are now obvious; it will appear lined with granulations and containing pus; the sequestra are often immediately visible, but all prolongations and recesses of the original cavity should be carefully explored for others, not only with probe and sharp spoon, but also directly with eye and finger.

Sequestra lying in the midst of granulations should first be gently seized with a pair of forceps (I always use an ordinary pair of artery forceps) to ascertain whether they are freely movable or not. It is most important that any one that does not seem quite free, but has apparently an end or projection caught in one or other extremity of the cavity, should not be broken in ill-advised and premature attempts at its removal; in its fixed position it acts as an excellent guide to recesses and pockets that might otherwise have escaped notice.

3. All granulations should then be removed with the curette; during this stage of the operation one should stop whenever necessary to pack in small gauze swabs to soak up the blood which now keeps obscuring the field of operation. In this way sequestra gradually become free; where previously hidden by granulations they now become visible. And many a recess and cul-de-sac in the bone, in which other sequestra may be found lying, will become apparent. All these small cavities must now be converted into widely-opened grooves by the use either of the curette or chisel, according as the bone is soft or hard. Each time the cavity is swabbed out the walls should be carefully examined for the small greyish points of granulations that mark the openings of diverticula

and secondary cavities; these it is very necessary to open up, whether they contain sequestra or not.

Radiograms showing the Result obtained by Sub-periosteal Resection of one Wall (pp. 141–149).

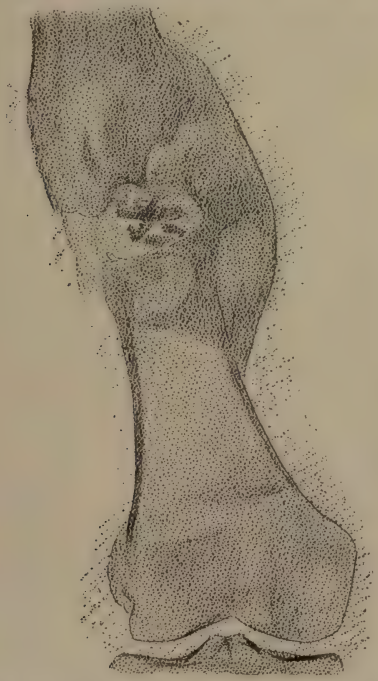
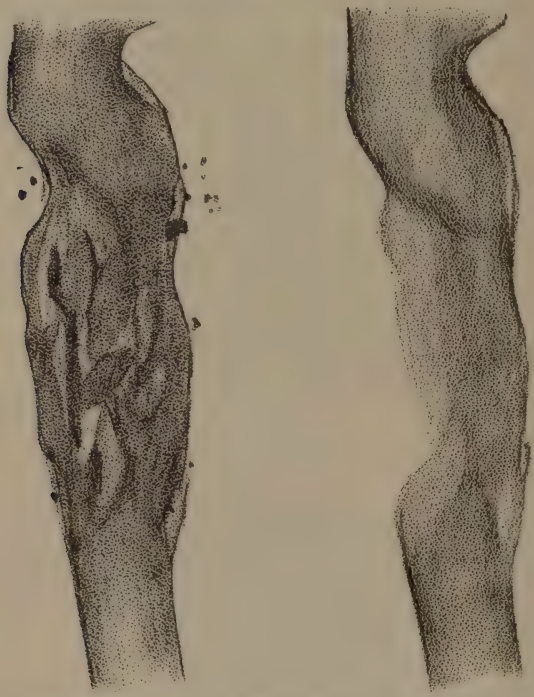


Fig. 80.—Patient thirty-four years old; wounded by a piece of shell, 24th September 1914. Ineffective curetting performed several times, the last on 30th March 1916. The X-ray, 15th April 1916, shows the ineffectiveness of these operations. Radical operations with removal of numerous sequestra, 11th May 1916; healed, 15th July 1916.

All other sinuses than the ones already opened should then be explored with the probe in order to make certain that they do not originate from any point

of bone disease not yet exposed and dealt with in the main cavity or its already discovered recesses. The sequestra should next be all removed, even if it



Figs. 81 and 82.—Patient aged thirty-five years; wounded by a piece of shell, 5th October 1914; sequestra present—enclosed in a cavity. Operation, 31st January 1916. X-rayed, 10th March 1916, showing the removal of the outer half of the circumference of the femur. September 1916 there still remained a superficial sinus.

be necessary to follow them far up and down the shaft. All granulations and foci of rarefying osteitis should be dealt with by vigorous curetting. In the case of an epiphysis, an excavation adequately per-

formed will sometimes leave nothing but the outside shell of bone.

Sometimes the shaft, thus weakened and attenuated, fractures, in which case, after a completion of the



FIG. 83.—Patient aged twenty-five years ; wounded by a piece of shell, 17th November 1914. There was present a cavity containing two large sequestra, despite two previous operations. X-rayed, 8th March 1916. Radical operation, 12th March 1916 ; healed, 1st April. On the 15th April he fell and fractured the bone, which, however, united well.

dressing, it will be necessary of course to immobilise as for an ordinary compound fracture. Such fractures usually unite well, just as do those accidental ones which sometimes occur in the course of an osteomyelitis.

The free incision of the soft parts that we have insisted on has as its object the complete removal of that wall of the bony cavity which is exposed by the operation. It is most necessary to carry out this stage of the



FIGS. 84 and 85.—Patient aged twenty-one years; wounded by a rifle bullet, 18th January 1915. X-ray (9th March 1916) showed a large granulating cavity without sequestra. Fig. 85 shows the result after removal of one wall of the cavity, 15th March 1916. Still under treatment in September.

operation with the utmost care, so as to make quite certain that there is no bony arch or ledge left bridging or overhanging a granulating recess of the cavity. This done, the walls that remain and form the sides of the gutter thus produced should then be removed so as to convert this gutter into a groove as wide and

shallow as possible—to transform it, in fact, into an almost plane surface; in this way the transverse diameter of the bone that remains is much diminished, a column of bone sufficiently thick to maintain the continuity of the bony lever still, however, being

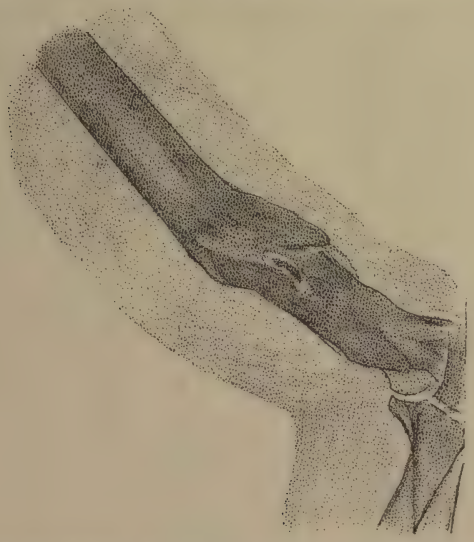


Fig. 86.—Patient aged twenty-five; wounded by a shrapnel bullet, 5th February 1915. There resulted a cavity containing a sequestrum despite two previous operations. X-rayed, 25th February 1916. Operation, 4th March 1916. Still under treatment in September, when I removed the anterior wall of the cavity. This I should have done at once at my first operation.

preserved. One need not be afraid of removing all the bone necessary, for it should be remembered that this hard bone left will before long be considerably reinforced by the progressive formation of new bone by the periosteum that was so carefully preserved during the first stage of the operation (figs. 81–93).

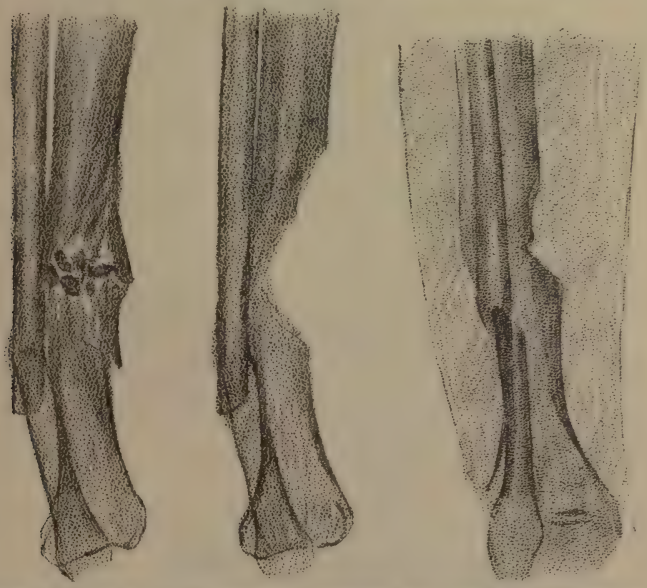
4. The object of these latter stages of the operation



FIGS. 87 and 88.—Patient aged thirty-nine; hit by a piece of shell, 13th October 1914. Several inadequate and unsuccessful operations. The cavity contained seven sequestra. X-rays taken respectively 3rd February and 27th May; almost cured in September.

is to bring about healing by such a utilisation of the soft parts as I must now explain.

It is essential, as I have already explained, that the soft parts should be allowed to sink into and occupy and—so to speak—carpet the floor of the groove that has resulted from the previous stages of the operation. This explains the necessity for the previous wide



FIGS. 89, 90, and 91.—Patient aged nineteen; wounded, 29th September 1915, by a rifle bullet; fragments removed 11th November 1915, and again 13th March 1916. X-rayed, 17th November 1915 and 15th April 1916, before and after radical operation. Cured, May 1916.

removal of the excess of new bone callus. The methods used to promote this desirable action of the soft parts are two :—

(*a*) *Packing.*—This consists in packing gauze into the cavity, whose walls soon become covered with granulations. These will later undergo ossification in

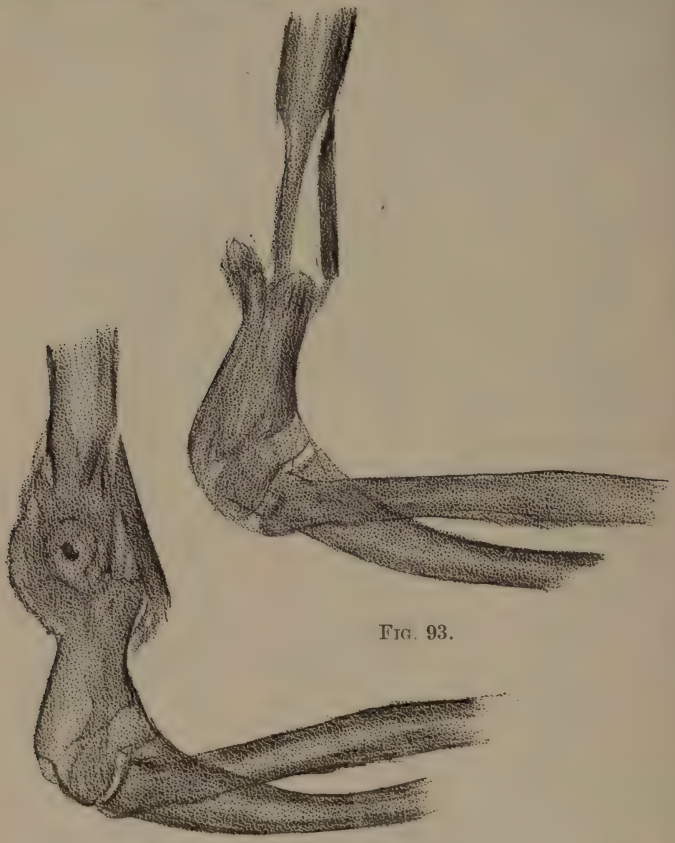


Fig. 93.

Fig. 92.

Shafts remaining Solid and Firm despite the Thinness of the Bridge of Bone left after Operation. In Fig. 92 the new Formation of Sub-periosteal Bone is still Transparent to the X-rays.

Figs. 92 and 93.—Patient aged thirty-three; wounded by rifle bullet, 9th May 1915; received for treatment, 16th June. X-rayed, 27th July (after an operation on 19th June for suppurative osteitis and arthritis of the elbow joint). Radical operation including the removal of a sequestrum, 28th August, elbow joint stiff at a right angle—musculo-spiral paralysis.

two different ways: one, from their deep surface, by the activity of the osteoblastic elements in the walls of the cavity; the second, and more important, by the deposit of bone elements from the periosteum,



Fig. 94.—Patient aged twenty-six; wounded, 18th December 1914. X-ray, 12th January 1916. On the 15th January excavation of the bone and removal of two sequestra; healed, 23rd February.

which with the muscles and skin becomes gradually drawn inwards to the depths of the cavity by slowly-acting retraction of this very granulation tissue. In this way in the end a thin depressed scar adherent to the bone results.

This is a slow process, but often the best—often indeed the only one that is practicable.

If one has to excavate an epiphysis, especially one of the large epiphyses at the knee joint, in which it is impossible to remove one wall fully without opening the joint, this remains the only means at our disposal. This makes gradual ossification from the periphery towards the centre of the cavity necessary; hence healing is slow, and often delayed by troublesome recurrences of rarefying osteitis. Generally, but not always, healing takes five to six months, sometimes occurring only after further secondary operations.

It occurs most quickly—but even in this case within a minimum period of three to four months—after operations on tunnels and cavities in the middle of the shaft of an easily accessible bone like the tibia.

(*b*) The immediate collapse of the soft parts against the floor of the newly-formed groove often allows of a great shortening of the period required for healing, a procedure that is analogous to the operation of Estlander for chronic empyema.

After simple incision for empyema the lung, shrunken and bound down by the fibrous visceral pleura, can no longer expand and fill the chest cavity and come into contact with the parietal pleura; on the other hand, the bony framework of the chest, drawn in by the progressive fibrosis within, soon reaches the limits of its elasticity and of its capacity for collapse. However, after the removal of the underlying ribs the subcutaneous and muscular covering of the thoracic wall may be utilised to fill the cavity, the result being an obliteration of the latter, sometimes due to an immediate collapse of the parietal pleura against the lung surface, but more often to a

more gradual approximation of its two walls, the parietal pleura and chest wall being now no longer able to resist the cicatricial pull from within. A suppurating cavity with rigid walls has thus been converted into a cavity with at least one collapsible wall.

This is exactly what we have achieved in such a complete removal of the roof of the sequestral cavity as allows the soft parts to sink into and occupy the groove thus formed.

To assure the fulfilment of this condition it will often be necessary to free the skin extensively. Especially around the opening of sinuses is it adherent and puckered up into funnel-shaped depressions which, adhering to the bone, would effectively prevent collapse of the muscles into the grooves. By horizontal undercutting till normal subcutaneous tissue is reached we can easily loosen and free the skin over a sufficient area and to a sufficient extent to allow the musculo-periosteal layer to fall inwards and occupy the excavated bony surface. When the muscles have become almost completely fibrous and the joint they normally act on is ankylosed, transverse division of them across the direction of the wound will often assist considerably in the attainment of this aim.

If this be done, direct packing of the cavity can be replaced by packing gauze between the skin and muscle so as to force the muscles into the bone groove, and at the same time counteract the constantly present tendency of the skin edges to invert.

In cases where all the recesses seem to have been well opened up and the remaining bone surfaces appear everywhere firm and compact, with no soft areas of rarefaction visible to the naked eye, we may

even attempt immediate suture, either incomplete or complete, of the skin ; a large drainage tube should be inserted either into the bony cavity or, where the muscles occupy and fill up the cavity, between them and the skin. Union in these cases, however, is always rather slow, because in unhealed war wounds operative interference always excites a revival of microbic activity, which is often astonishingly severe, although the original wound may have been of long standing ; there reappear the green pus, even the superficial sloughing of the edges of the incision, the abundant and profuse and fetid suppuration of the original infected wound ; even necrosis of a thin layer of the excavated bony surfaces is not rare. Careful supervision is necessary then in these cases. The chief danger arises from the formation of a hæmatoma, that forms so fine a bed for infection. All precautions should therefore be taken to prevent this happening by firm bandaging of the limb. If union of the edges of the wound results, the drain should be removed at the end of a week, and in exceptional cases final healing will rapidly occur.

Usually, however, a cavity and sinus persist for a variable time, but these gradually decrease in size and finally heal. Often either the sinus remains constantly open and discharging, or else it closes and reopens after a longer or shorter period of temporary healing ; and it heals finally either after the spontaneous elimination of a small piece of necrosed bone, or else after the performance of one or two slight secondary operations, which may now be quite correctly described as " scraping " or " curetting " ; not rarely a small sequestrum hidden away in a recess has been overlooked ; or in scraping out the cavity the curette

has spared some small fragments destined to undergo subsequent necrosis; or again, secondary necrosis may occur at certain projecting points of the new bone surface left by the operation. Such occurrences are, however, not sufficiently frequent or serious to contra-indicate attempts to suture the wound; much time may thereby be gained at the expense of a possible slight secondary operation. Often the attempt at primary, or at least early, union fails, a profuse blood-stained discharge appears, the skin becomes red and inflamed. It then becomes necessary to remove the stitches and resort to packing with gauze.

These general rules must not be followed too rigidly; of course they will require modification according to the local necessities of each case, especially those anatomical relations that should regulate most definitely the means of approach to the affected bone, and to a less extent also modify the details of the operation.

(*a*) **The shaft of a long bone with an extensive subcutaneous surface or border**—*e.g.* the tibia (subcutaneous inner surface), the ulna (subcutaneous posterior border), and the clavicle (subcutaneous upper surface).

These bones are very easily reached over their whole length by an incision running parallel to their subcutaneous surface and half-way between its borders; the periosteum and subcutaneous coverings of this surface should then be completely elevated from the bone by the use of the rugine; the cavity should be opened and converted into a gutter, the walls of which are then to be cut away so as to give them as gentle a slope as possible. Any operation performed differently through a sinus that does not lie in the line of this incision of choice is on that account alone to be

condemned. The method of approach for excavation of the two epiphyses of such a bone is identical with this for the shaft.

In cases where the cavity lies in the middle of the shaft, after removal of the bridge of bone—often of great width in the tibia—and levelling of the edges of the cavity have been performed, the two flaps, consisting of periosteum, subcutaneous tissues, and skin, usually sink in quite readily and occupy the floor of the groove thus formed : if they lie in good contact with this, primary union may be attempted, the limb being dressed and firmly bandaged.

(*b*) **The shaft of a bone everywhere surrounded by a thick mass of muscle, as in the femur and humerus.**—In exposing these bones it is necessary to remember their relations to the vessels and nerves. Sinuses of the femur often open internally or (in the lower third of the bone) posteriorly. Now in these directions lies the artery, which prevents freedom of incision and operative manipulation. The only good position in which a free incision can be made is the outer aspect of the thigh, where, if necessary, it can be extended from the great trochanter to the external condyle. It is usually most convenient to expose and resect the antero-external part of the enlarged bone ; into the cavity thus formed and lined with periosteum the quadriceps extensor muscle sinks ; gauze packing may be used to keep this in position. If the knee is ankylosed, however, this may be more easily effected by simply dividing this useless muscle transversely.

The different parts of the humerus requires separate consideration.

In the upper portion, provided the shoulder joint is

not ankylosed, great care must be taken not to injure the circumflex nerve supplying the deltoid. One should therefore approach this part of the bone from the front through the groove between the deltoid and the pectoralis major, or else a little further out through the anterior fibres of the deltoid.

This incision, which lies just external to the biceps, can at need be extended downwards along the anterior surface of the bone through the fibres of the brachialis anticus. It is the only suitable incision for reaching the middle third of the shaft, the musculo-spiral nerve here winding round the other surfaces of the bone. Use may be made, however, of the existence of posterior sinuses in the upper third of the bone, behind the posterior border of the tendon of the deltoid. By such an approach either the anterior or the external wall of a cavity can be removed, the deltoid —which may be divided in cases of ankylosis of the shoulder joint—coming to occupy the bony groove thus produced.

Good access to the lower half of the shaft may be obtained by either one or, if need be, two vertical incisions corresponding to the internal and external supracondylar ridges; such an external incision, however, should not reach higher than the lower third of the shaft, so as to avoid crossing the track of the musculo-spiral nerve.

If there is a posterior sinus from the lower third of the bone, a vertical incision deepened through the triceps serves as an excellent means of approach; a similar approach through the triceps to the upper third of the bone between circumflex and musculo-spiral nerves is possible, but is rendered inconvenient by the thickness of the muscle at this point. In

places like this, where one has to operate through a thick muscular mass, either packing between skin and muscles or else closing the wound with drainage will be found necessary.

The radius should be reached on its outer side. The incision should be deepened through an intermuscular plane, the muscles here being very easily separated and retracted. Its lower end should be exposed either from the back or from the outer edge of the forearm.

The surgical surface of the fibula is its outer surface, which should be reached by passing between the peronei in front and the muscles of the calf, *i.e.* along the external intermuscular septum; it should not be forgotten that the external popliteal nerve winds round the neck of this bone.

(*c*) **Epiphyses and short bones.**—I have already dealt at sufficient length with the diffuse osteitis of such cancellous bone; I have pointed out the impossibility of completely removing one wall of the cavity, the necessity for methodical packing of the cavity, and the length of time necessary for cure. I will say no more, then, about the large epiphyses at the knee joint. Some details of the treatment of the disease when it occurs in the bones of the foot are, however, necessary.

In the foot all operations on the posterior bones of the tarsus and the cuboid should be undertaken from the outer side, whilst the scaphoid and cuneiform bones should be approached from the dorsum or inner border of the foot. The incisions should be in the long axis of the foot, so as to avoid damaging the tendons. As a general rule, one should avoid using the plantar surface.

Cases of caries of the os calcis are most obstinate. Removal of diseased bone leaves a cavity that it is most difficult to heal, and at times one is forced to resect *en masse* a considerable part of the bone. Through and through drainage by a counter-incision behind the internal malleolus is easily achieved.

After excavation involving the anterior tarsal bones

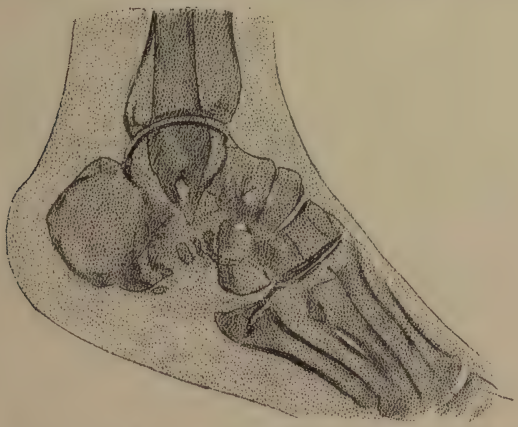


Fig. 95.—Patient aged twenty-four; wounded by a piece of shell, 22nd June 1915; succession of abscesses and persistence of sinuses. X-rayed, 2nd March 1916. Rarefying osteitis and sequestra. Foot fixed in equinus and slight varus. Radical operation, 27th March. Discharged with a small sinus, 28th July.

and the bases of the metatarsals—whether such excavation has been performed early or late—the foot should be immobilised at a right angle, and this position maintained in plaster over a long period. This is necessary if one wishes to avoid that most troublesome complication—fixed equinus of the anterior part of the foot, the result of permanent flexion at the disorganised mid-tarsal joint. This flexion is produced

by progressive contraction due to inflammation and subsequent fibrosis of the muscles and ligaments of the sole of the foot, and the resultant shape of the foot is comparable—only with more dropping of the front part of the foot and less advance of the heel—to the pes cavus of infantile paralysis. Sometimes the destruction of bone is so extensive and the contraction of the plantar ligaments and tendons so excessive, that the deformity appears even after a long course of immobilisation, that has, however, proved insufficient for the production of ankylosis in a good position. Whether this flexion has been inevitable or the result of careless treatment, it should be corrected in either case by transverse tarsectomy—linear unless there be a varus element in the deformity, when it should be cuneiform : this operation is most easily undertaken through a longitudinal incision along the outer border of the foot, just as in tarsectomy for club-foot.

(*d*) **Flat bones.**—Thick-walled cavities in the iliac crest should be exposed and dealt with through an incision parallel to the crest itself. Similarly, the outer surface of the ileum should be approached by splitting the gluteus maximus in the direction of its fibres.

In the scapula, the two favourite positions for enclosed sequestra are the axillary border and the spine ; I have met with several cavities in the root of the acromion.

(*e*) **Ankylosis of joints with sinuses present leading to the epiphyses.**—In such cases the sinuses lead down directly to the focus of diseased bone, and can, after being incised, generally be utilised for the passage of the curette ; in cancellous bone the chisel is but rarely of

use. If a more extensive and radical operation is indicated, the classical incision for the approach to the joint for resection should be used.

If the joint be ankylosed in bad position, this should be corrected by an orthopædic resection—the technical details of this method will vary with the amount and nature of the desired correction ; it will be understood that in such cases one must not promise any great return of movement.

I have described the operation that should be performed immediately in the case of sinuses of osteomyelitic origin that have been allowed to become chronic, the patients, for lack of a proper decision to perform a radical operation, having been allowed to waste a year or more passing from one hospital to another. Much more rapid results can be obtained by very much less extensive and difficult operations by a surgeon, who by reason of his special knowledge and experience knows exactly at what moment to intervene alike in the case of the primary as of any secondary operation that may become necessary.

Figs. 96–100 are the radiograms of patients who have remained under my charge from the early days of their wound, when they were first admitted with severe infection into hospitals. Those of the fractured femur need no commentary, except that a study of the dates in these cases shows that very late final healing must be expected even in the hands of surgeons competent to practise the surgery of bone.

Figs. 98–100 are intended to show that in compound fractures into the elbow joint I restrict myself to simple removal of fragments and sequestra, not a real formal resection. I do not wish to imply, however, that better results might not have resulted had early primary

resection been performed before the onset of signs of infection; but if the shattering of the bone has not been excessive, anklyosis at a right angle (fig. 100) gives a better result than that furnished in most cases



Fig. 96.

that have been subjected to full secondary resection. A good example of this is shown in figs. 98 and 99, where the extent of the damage (to the lower end of the humerus) was very great.

I shall finish by giving some idea of the way in which cases are treated in my hospital practice, cases that

arrive some two to five days after being wounded, and hence at a time when it is too late to attempt to prevent infection. If there be no suppuration, of course no operation is necessary, and the fracture is immobilised

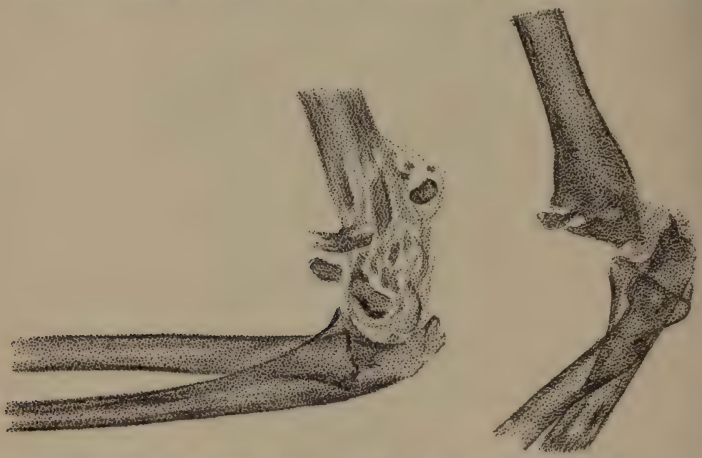


Fig. 97.

Figs. 96 and 97.—Patient aged twenty-eight; wounded by a piece of shell, 11th May 1915. Incision and removal of fragments causing severe inflammation, 15th May. Bone immobilised in Delbet's apparatus. Several small sequestra spontaneously emerged. Radical operation with removal of eight sequestra, 3rd September 1915, then again 29th November 1915 and 5th January 1916. X-rays 3rd November 1915 and 16th February 1916 respectively. Healed by the end of July 1916.

and treated just like any simple fracture. In these, of course, secondary infection may occur; but when it does, it is but moderate. It occurs especially, though not inevitably, when foreign bodies remain in

or near the bone, and especially often also in wounds due to bullets whose covering has been torn or that have broken up into fragments. But even in these conditions aseptic enclosure of the fragments is possible. In such cases, then, it is not necessary to intervene at



FIGS. 98 and 99.—Patient thirty-one years old; wounded by a piece of shell 28th September 1915; shattering of the lower end of the humerus, with a very large wound behind and on the outer side; suppurative arthritis with gas formation, incision, free drainage, removal of all free and adherent fragments. Radiograph, 26th December. Healed with the formation of an articular pseud-arthrosis of the elbow, 10th February 1916. When seen again (fig. 99), 8th September, the elbow joint was flail as regards lateral movement and extension. Flexion could be actively carried out, and reached the right angle with a fair amount of stability. The musculo-spiral nerve, which had been temporarily paralysed, had recovered; the ulnar nerve remained paralysed.

once, but one should be prepared for the probable onset of inflammatory signs. Fortunately the necessity for the removal of such fragments arises most often in cases where this is most easy to accomplish, but one would never dream of attempting to remove all the

fine metallic powder revealed by radiography. The information furnished by radiography, however, is not always absolutely accurate, for sometimes a piece of lead will strike a piece of bone and discolour it, so that it becomes opaque to the X-rays and throws a shadow indistinguishable from that of a metallic foreign body.

These fractures should be carefully watched; the



Fig. 100.—Patient aged twenty-three; wounded by a bullet, 25th September 1915; severe inflammatory complications. X-ray, 25th March 1916. Radical operation with removal of a sequestrum, 3rd April 1916; healed, 29th May 1916, with ankylosis of the elbow-joint and musculo-spiral paralysis.

temperature carefully taken; the absorption of aseptic blood effused at the time of injury is always considerable; there is usually some œdema and inflammation of the soft parts. The callus is often bulky and tender; some infection generally exists at the point of entrance of the projectile. The least suppuration at this entrance wound should make us fear its exten-

sion to the bone itself, an extension which may take place slowly and lead to osteitis even after consolidation of the fracture is already far advanced, but no risk should be run by a premature and harmful opening up of the seat of fracture during the period of early aseptic infiltration and inflammation.

A similar course of action is adopted if, in the absence of foreign bodies, the wound is large and the suppuration moderate in amount. Immediate treatment is regulated by the severity of the inflammatory signs in the soft parts; when incision and drainage of these is necessary, all loose fragments of bone should be removed as well as adherent fragments, for these latter are practically certain to necrose. But this operation, which certainly limits the spread of the traumatic osteomyelitis, does not entirely do away with the septic process, and it is the rule, almost without exception, that the ends of the fractured bone undergo necrosis and form secondary sequestra even in cases where one has succeeded in removing all the primary ones. Hence sinuses are practically inevitable, and later operation a necessity, but this should not be performed too soon; the abscesses that often form round the infected seat of the fracture should, in the meantime, be opened without interfering with the bone condition at all. It is necessary to allow time for sequestration to occur, for until it is complete it is impossible to determine the limits of the necrosed bone; and during this period too the bony fragments act as a support to the periosteal sheath which, by producing new bone, is going to re-establish the continuity of the bone. In young patients it is often astonishing what degree of regeneration can obtain in fractures so comminuted or with

such loss of substance as to make one fear the production of a false joint.

For these reasons then, although successive sequestra which find their way into the sinus track should be removed with forceps, the radical operation we have described should not be attempted too soon; nor too late either, in order that the newly formed bone enclosing the sequestra may not itself become the seat of a progressive rarefying process. The time necessary for the completion of sequestration varies directly and almost definitely with the size of the bone; in the femur it takes two or three months, in the radius or ulna five or six weeks. At the end of these respective periods, and after careful radiographic study, the operation of removal of all sequestra and obliteration of the cavity should be practised. Healing after this is almost always slow; in a large bone it often takes five or six months. Hence a fractured femur often takes altogether some eight or ten months from the date of reception of the wound before final healing is obtained, and this period will be longer where a second operation or, as in some cases, several at six-weekly or two-monthly intervals become necessary.

Again, the re-opening of abscesses and sinuses sometimes occurs quite a long time after apparently final healing. And if ten years hence some one were to show me some of these cases, especially of the lower third of the femur, still continuously or intermittently suppurating in spite of successive and well-carried-out operations, I should answer that my former knowledge and experience of the spontaneous osteomyelitis of childhood had led me to expect such things. It has also led me to expect cases—exceptional ones certainly

—in which, repeated radical operations having failed to arrest progressive invasion of the bone by disease, late amputation will be necessary. Already I have been forced to amputate three thighs and disarticulate one hip joint after vain attempts to cure such a suppuration accompanied by chronic septicæmia. All four cases are now healed and cured.

## CHAPTER IV

## THE AFTER-EFFECTS OF WOUNDS IN JOINTS, MUSCLES, AND TENDONS

Even after firm union and final healing many cases of gunshot fractures—even where there has been no direct original involvement of the joint—end with ankylosis, or with considerable limitation of the normal range of movement of joints due to lesions either of the articular tissues themselves or else of the muscles that are normally concerned in their movement.

Too often such cases are sent in large numbers to a centre of physiotherapy, where too often also, in the absence of careful examination and accurate diagnosis of the cause or nature of their disability, they are submitted to a full course of treatment—massage, the various forms of electricity, baths and douches, passive and instrumental movements. All these methods of treatment, of very considerable benefit in certain cases, are in others not only useless but often harmful.

The differentiation of these cases is often a matter of difficulty, I know, because the various factors that have to be taken into consideration are numerous and often contradictory ; and if one attempts the classification of the cases met with on some pathological or etiological basis, it will soon be found that the over-

lapping of categories is so frequent and so confusing as to render impracticable the best thought-out and most comprehensive scheme.

## 1. The Pathological Varieties of Ankylosis, Stiffness, and Deformity of Joints

Ankylosis means the limitation in any way of the normal range of movement of a joint,[1] and it is necessary first of all to remember that ankylosis comes into being only when the pathological process that causes it has ceased to exist. Because of ignorance or forgetfulness of this fact many serious errors of treatment have been committed. As long as the pathological condition causing the ankylosis is still in existence, it and not the ankylosis should be the object of treatment.

Ankylosis, thus defined, includes, then, all degrees of interference with the movement of a joint, from the slightest diminution of one movement to complete absence of all movement; hence, clinically, ankylosis is either complete or incomplete.

If, however, we wish to classify cases of ankylosis on an anatomical basis, we distinguish two varieties according to whether the causative lesion is intra-articular or extra-articular.

1. *Intra-articular ankylosis.*—This is the result of an arthritis—plastic, serous, or suppurative—which has produced in the joint the following pathological conditions :—

[1] In England " ankylosis " is generally used in a more limited sense, including only true bony ankylosis and firm fibrous ankylosis, so that the classes here described as due to extra-articular lesions would be included under restriction of movement of a joint rather than under ankylosis.—(Ed.)

(*a*) The articular cartilage of the ends of the bone becomes eroded and gradually disappears, thus leaving bare the surfaces of the bones, so that they subsequently undergo bony or firm fibrous union.

Bony ankylosis, the usual result in adults of a suppurative arthritis, is, of course, necessarily a complete ankylosis.

Interosseous fibrous ankylosis, much less common in such cases, is almost always very firm and practically complete.

(*b*) Next in a theoretical classification of these intra-articular lesions would come the obliteration by plastic inflammation of the synovial pouches and recesses, and the contracture of capsule and ligaments ; these are usually associated with some disintegration of the articular cartilage and deformity of the articular surface of the bones ; in these cases incomplete ankylosis is the rule ; sometimes, however, the loss of movement is so great that it is practically complete.

The original lesion in such cases is always an arthritis ; but where the articular surfaces remain normal or almost so, with only slight erosion of the cartilage as the result of a dry arthritis, the synovial and ligamentous changes should be clinically regarded as constituting an ankylosis rather of peri-articular origin.

2. *Extra-articular lesions.* — These occur either in the bone or in the peri-articular soft parts.

(*a*) When the *articular end of a bone* is deformed, the result either of excessive callus formation or of an excessive inflammatory production of sub-periosteal deposit, a mechanical disability of the joint results.

The purest example of this resulting from excess of callus occurs in supra-condylar fractures of the

humerus, when the badly reduced lower end of the shaft limits flexion of the elbow joint.

The classical example of joint disability from inflammatory hyperostosis is the incomplete ankylosis of the knee following osteomyelitis of the lower end of the femur. Instead of gliding round the articular surface of the femur like the strap of a helmet round the chin, the tibia finds its progress in flexion of the knee arrested where the femoral condyles are enlarged.

The disability is increased when in addition to this bony obstruction there exists also more or less fibrosis and contracture of the synovial membrane and ligaments, the joint having been the seat of a chronic inflammation by continuity from the diseased bone. In such a case we get an association of both peri- and intra-articular lesions, but the latter are of but secondary importance; and the all-important fact to remember in considering the treatment is that the extra-articular cause of the trouble is bony and unyielding, causing a mechanical arrest of movement that no mere manipulation or forcible correction will succeed in overcoming.

(*b*) The *lesions of the peri-articular soft parts* may involve any of the neighbouring tissues, may consist in thickening and fibrosis of the intermuscular planes and septa, in the obliteration of tendon sheaths and their adherence to contracted tendons, in atrophy and fibrosis of the muscles.

At the same time, as we have already described as occurring in the joint lesions of chronic osteomyelitis, the inflammation extends inwards to involve to a variable degree the capsule and synovial lining of the joint. In exceptional cases parts of these peri-articular tissues actually undergo ossification, and

form bridges of bone which constitute one form of extra-articular bony ankylosis; in such a condition all methods of treatment short of operation are hopeless.

Here again, then, we find an association of lesions within and without the joint, but the original lesion is an extra-articular sclerosis, which in itself is amenable to cure, or at least to improvement, without the necessity for a bone operation.

It will be understood, then, that up to a certain point, though always with the reservations we have made, cases may be classified, upon an anatomical basis, into stiff joints and ankylosed joints proper.

The cases of mere stiffness—almost always extra-articular in its origin—are associated especially with sclerosis of the soft parts.

The cases of ankylosis—properly so called—result chiefly from alterations in the articular ends of the bones.

3. *Lesions of the muscles and tendons.*—We have been dealing so far with articular lesions, lesions due to suppurative or plastic arthritis and peri-arthritis, involving the structures of the joint itself or the parts surrounding and enclosing it. We have still, however, to consider abnormal limitation of the range of movement of a joint due to a pathological condition situated at a distance from the joint, resulting from some interference with the equilibrium normally maintained between the groups of muscles acting on the joint.

Such lesions are of two different varieties:—The paralysis of certain muscles with overaction of their antagonists. The retraction or contracture of certain muscles that results in more or less permanent approximation of their points of origin and insertion.

Every one, for example, is familiar with the drop-wrist of musculo-spiral paralysis, the foot-drop of external popliteal paralysis. Such cases, at least when uncomplicated, belonging, as they do, to a very special department of surgery, should be studied in connection with the phenomena of traumatic lesions of the peripheral nerves. But in the surgery of war these cases are often complicated by a rapidly developing secondary stiffness of joints due to sclerosis of muscles, joints, and ligaments, to the importance of which I wish to draw special attention.

From my experience of severe suppuration and diffuse inflammation of the limbs in civil surgery, I cannot say that I can detect much difference between the after-effects in such cases and those in similar lesions occurring during the war and due to infected projectiles. The muscular atrophy and the loss of movement due to adhesions and sloughing of tendons of our war experience seem to me to be identical with what we saw in civil practice. Before the war we were quite familiar, for instance, with those common results of extensive inflammation in the upper limbs, viz. fingers blue, cold, and stiff with thin transparent skin, wrists frequently fixed in semiflexion and semi-pronation. When one got the chance to dissect such a limb the muscles of the forearm were found to be fibrous and greyish-red, their normal colour almost entirely absent, the intermuscular planes obliterated and fibrous and replaced by masses of tough fibrous tissue strangling the nerves and blood-vessels ; the tendon sheaths adherent to their tendons ; articular ligaments hard and contracted ; and where the immobilisation, often in a bad position, has been of long duration, considerable erosion of the articular cartilages.

What does seem to me peculiar, however, in the wounds of this war is that condition of atrophy combined with sclerosis and contracture at times induced in certain muscles by even a slight injury, for example, by simple penetration by a bullet. Of course such progressive sclerosing myositis is more likely to result where suppuration has occurred, but I have seen it several times, especially in the calf muscles, follow mere penetration by a bullet, the tract healing in a few days without suppuration beneath the small scabs that mark the points of entrance and exit. This condition seems akin to the progressive sclerosis that follows obstetrical injury to the sterno-mastoid muscle and results in the development of torticollis, the muscle in time becoming completely fibrous throughout its whole length and thickness.

The nature of this progressive sclerosis in torticollis, unknown in connection with subcutaneous rupture or aseptic wounds of any other muscle, has been the subject of much controversy; I know that the chief part in its production has been attributed to congenital syphilis, the influence of the obstetrical rupture of muscle fibres being either relegated to a position of but secondary importance or else denied altogether. I am willing to grant that the pathogeny of this condition is still as uncertain as that of this certainly traumatic muscular contraction to which we have just referred, a contraction accompanied by an induration and atrophy of the whole muscle mass altogether out of proportion to the extent and severity of the original wound. I may add also that such contraction does not seem to be associated with any lesion of the nerve-trunks of the limb, which, clinically, always appear quite intact.

Possibly, as has also been maintained as regards congenital torticollis, this may be a form of that curious ischæmic contracture of muscle which we see from time to time following simple fractures, especially in young people, and almost exclusively in simple fractures about the elbow joint or of the bones of the forearm.

The same thing occurs too in cases of mere contusion or rupture of muscle associated with the formation of a large hæmatoma and of too prolonged constriction of the limb by a tourniquet; hence it would seem that the muscular ischæmia is the primary cause of the myositic degeneration. This would explain the rôle played in its production by constriction or compression by too tight splinting; also the occurrence of this lesion in the absence of any such external cause of pressure in cases where trauma has led to great swelling, with effusion of blood and widespread œdema, and hence to compression of blood-vessels, and to a certain extent also of nerves.

This is not the place to discuss the exact nature and cause of this ischæmic contracture, to decide whether the circulatory condition is primary or secondary, whether this acts exclusively or directly on muscle fibre, whether the nerves, at first apparently unaffected by it, undergo a secondary compression. My object has only been to compare the phenomena of this ischæmic contracture with those of the fibrous degeneration of muscle that we see so frequently in cases of gunshot wounds, in which there may or may not be an accompanying fracture, and in which suppuration is severe, or slight, or absent.

Joints that have assumed fixed positions on account of interference with the equilibrium of the various

groups of muscles acting on them do not as a general rule undergo secondary changes, at any rate for a long time; such fixed positions are easily corrected by tenotomy. This may be seen every day in the various forms of paralytic club-foot, in which, when there does occur an obstacle to full correction, this is not of an inflammatory origin, but consists merely of an overgrowth or deformity of bone due to abnormal transmission of pressure through the foot.

In the case of war injuries, however, joints originally perfectly sound and free, often seem to become fixed in bad position with extraordinary rapidity. It is practically certain that they are really the seat of a subacute inflammation. Even in cases without fracture, or in which suppuration is absent, one is often struck with the relative intensity of the immediate swelling, the effusion of blood, the firm, and at first solid, œdema. All these appear at their maximum in cases of compound fractures; for example, with fracture of the femur or of the humerus the œdema is very considerable in the leg and foot and in the arm and hand respectively.

We do not know to what distance up and down from the actual wound this œdema may be directly involved in the infective process, and liable to end not in simple absorption but in fibrosis. Sometimes it certainly is infected. I have been very much struck with a phenomenon which is quite unique in my experience, and I think most interesting in this connection. In a patient with a very severe compound fracture of the femur received some months previously I forcibly corrected under a general anæsthetic an equinus position of the foot, and in so doing brought about an acute suppurative inflammation of the ankle joint.

This unfortunate case of an infection, latent but obviously severe, and awaiting only such an opportunity to become active, explains why, in a considerable number of cases of deformity of joints due to muscular sclerosis and retraction, a secondary stiffness of arthritic or peri-arthritic origin so often occurs. To an already existing abnormal position of the joint has been added a subacute or chronic inflammatory process.

## 2. The Treatment of Ankylosis and Stiffness of Joints

### A. *Preventive Treatment*

In every case of inflammation of a joint, whether the result of its direct involvement in a wound or whether indirectly produced by fracture of a neighbouring epiphysis, we must anticipate from the outset the occurrence of its almost certain ankylosis, partial or complete. Our duty then is plain—to fix the joint so that if or when ankylosis takes place it will leave the limb in the position which is most favourable to, and most compatible with, its greatest subsequent utility.

The first indication, then, in the treatment of articular inflammation is the most rigorous immobilisation of the joint in this position of election.

No one would dream of contesting this rule in so far as it refers to suppurating joints, which should be fixed as early as possible in some suitable apparatus compatible with careful observation of the inflamed tissues and with the positions of the wounds or surgical incisions. But before the application of this, for which a general anæsthetic is very often necessary,

we should strive by means suitable to each particular case (continuous extension, adjustable or flexible splints, successive starched bandages) not only to approach gradually the attainment of the ideal position, but also to prevent any such further development of mal-position as only too surely would happen if this precaution were neglected.

The respective mal-positions spontaneously and inevitably developed by each of the large joints of the limbs when inflamed are as follows :—

At the hip joint, flexion, adduction, and internal rotation.

At the knee joint, flexion.

In the foot, the position of equinus.

At the elbow, pronation and extension of 135°.

At the wrist, semi-flexion.

Now, not only are these respective positions disadvantageous in the actual treatment of the existing inflammation of the joint, but they will all, without exception, on the completion of ankylosis constitute grave functional disabilities.

The positions which are most certainly both ideal during the acute phase and later, after ankylosis, the most favourable from the point of view of utility of the limb, are :—

At the hip joint, the vertical position, *i.e.* neither flexed nor hyperextended, neither adducted nor abducted.

At the knee, full extension.

At the ankle and tarsal joints, the foot at right angles to the leg, or even 12° to 18° less than the right angle, the foot neither in varus or valgus.

At the shoulder, the arm by the side of the trunk or in slight abduction and flexion.

At the elbow, a right angle, the forearm midway between pronation and supination.

At the wrist, forearm and hand in one straight line ; for an inter-phalangeal or metacarpo-phalangeal joint, full extension.[1]

I know quite well that there has been an attempt to systematise the extension of the wrist joint to 25° to 30°, the extension of the elbow to 135°, with the forearm in full pronation, because these positions are alleged to give better functional results in certain manual occupations. For almost all the ordinary acts of life, however—*e.g.* in eating—these latter positions are unsuitable, and hence to be condemned, except perhaps in a few cases with special occupational requirements.

Complete ankylosis of the tarsal and ankle joints is quite compatible with very fair powers of walking if the foot has been maintained at a right angle to the leg, with good powers of walking if this angle is slightly acute. In cases of simple stiffness of the

[1] There is room for a slight difference of opinion as to the ideal positions of joints. At English orthopædic centres the positions adopted are usually the following :—

At the hip, extension and slight abduction, with the foot turned a little out.

At the knee, full extension.

At the ankle, right-angled position, with the foot neither in varus nor in valgus.

At the shoulder, abduction to about 60°.

At the elbow, usually flexion to 100°, with the forearm in the position of supination. Some, however, prefer a right angle or less, and some prefer full supination.

If ankylosis of the elbow is expected, the angle at which it is set should depend upon the patient's work.

If loss of pronation and supination is expected, the position should be semi-pronation ; if it is expected that these movements will return, the position should be that of full supination.

At the wrist, extension to 45° beyond the straight line.

At the metacarpo-phalangeal and the inter-phalangeal joints, very slight flexion.—(Ed.)

ankle joint with retention of a certain range of movement flexion should at least reach, better pass, the right angle in order to allow of fair walking. Ankylosis or stiffness at an obtuse angle, *i.e.* in equinus, constitutes a very grave disability. The first mechanical result of this is an elongation of the limb; this certainly may not be a disadvantage in a previously or simultaneously shortened limb, especially if the patient is fitted with a surgical boot in which the heel is raised more than the fore part, so that he walks in equinus. But if, on the other hand, the limb is of normal length, then the patient, walking on the heads of the metatarsal bones with the heel in the air, has to flex the knee to correct the lengthening of the limb. In slighter cases of this deformity the patient does put the sole flat to the ground in walking, but this necessitates an obliquity upwards and backwards of the leg, which again is corrected by an upward and forward obliquity of the femur; this puts abnormal tension on the knee joint, which in time becomes a real "genu recurvatum."

(*b*) When the joint does not suppurate, the inflammation having been but serous or plastic in its nature, an inflammation by contiguity from a fractured epiphysis, many surgeons—although I believe their number has decreased since the war—are opposed to immobilisation. In my opinion they are wrong; absolute immobilisation in plaster seems to me still the best means of resolving the inflammation, of lessening the chances of ankylosis, or at least of limiting its extent. Ankylosis in these cases results not from the immobilisation but from the inflammation.

(*c*) This does not mean, however, that the immobili-

sation of a healthy joint is quite a harmless procedure ; its ill-effect varies, however, with the age of the patient, with the joint immobilised, and with the nature of the lesion that is being treated.

To consider the effect of age first : in a child immobilisation of a normal joint hardly ever results in any stiffness ; a knee joint that has been immobilised in plaster for months in a patient with hip disease soon regains almost of itself its original range of movement. This is not so, however, in older patients, especially if the joint has been fixed in a bad position ; the stiffness that results in such a case is usually in direct proportion to the age of the patient.

The tendency to stiffness is specially noticeable in small joints where the articular surfaces fit closely ; the ready stiffening of the joints of the fingers is a good example of this. It is not at all uncommon for old people to develop obstinate, troublesome, and disabling stiffness of shoulder and fingers in cases where for some more or less limited lesion the whole limb has been fixed perhaps only in a sling, a lesion that could with a little care very often have been as well, and much more wisely, treated by allowing complete freedom of movement to these joints.

Consequently in the treatment of gunshot fractures we should aim at immobilising absolutely the fracture itself, and at the same time reducing to a minimum all restriction to the movement of neighbouring parts. Extensive plasters—either bridged by metal bars or with cut-out windows—which immobilise the whole limb are much the best form of splint for wounded men during their evacuation to the base, but once arrived in a base hospital, these should at once be

replaced by some other form of splint. For the arm and the thigh I believe, whenever the positions of the wound allow of its application, that none can surpass the spring extension apparatus of Delbet; in the leg one should leave the foot free as soon as possible by applying Delbet's walking plaster splint.

I know of course by experience that because of the presence of inflammatory troubles one cannot always do what is most desirable, that infective complications often upset our plans. But in most cases it is possible to apply if not the most ideal apparatus, at least the second best. I must, however, keep to general principles, since the technique of the application of splints does not fall within the scope of this book.

In the upper limb, as I have said, stiffness of the fingers and shoulder is often due to the abuse of immobilisation even in a sling. In the lower limb the most frequent and the most disabling lesion is talipes equinus with slight varus—the fixation in extension of the ankle joint—but the common cause of this is rather a lack of immobilisation. Two types of cases have to be considered, according as the wound occurs in the foot or in some other part of the lower extremity.

When a focus of bone and joint suppuration occurs in the foot, if the wounded man be left to himself to adopt what attitude he please, he will lie most often on the affected side (the limb lying externally rotated), sometimes, however, on the sound side (the limb in internal rotation), but in either case he will bend the knee and plantar-flex the foot. In this position the muscles are relaxed, and the weight of the bedclothes is avoided.

During the acute phase, whilst the foot is inflamed and swollen, whilst the wounds are still open and profusely discharging, we are often forced to leave things as they are. But as soon as it is possible we should, under an anæsthetic, immobilise the foot at a right or slightly acute angle in an interrupted plaster splint, and ankylosis, almost inevitable in the circumstances, will occur in a good position.

Lesions of the leg and thigh in which originally the foot is quite normal end too often in a fixed position of equinus ; this position is especially to be guarded against in cases of fracture ; but it is not uncommon following simple flesh wounds, even an aseptic bullet track. In these cases the instinctive attitude of rest and ease, as in the former case, consists in lying on the sound side, with the knee flexed and the foot dropped ; contraction and then retraction of muscles come into play, the bad position becomes fixed, and finally the joint stiffens. Deep muscles often share in the contraction and the toes become clawed, which considerably adds to the functional troubles. One must not imagine, moreover, that the deformity can be avoided by getting the patient up ; a fruitful cause of permanent talipes equinus or drop foot is the too early permission given to men wounded in the leg to get about on crutches. Fearful because of pain or inconvenience of putting weight on the foot, they flex the knee and let the foot drop.

In bed, lying on the sound or on the wounded side, they adopt the same position, which is thus maintained fixed both night and day. When the wounds are healed and free from pain, the knee movements almost always return quickly, but the drop foot persists.

From this knowledge of the cause one can easily

deduce the necessary preventive treatment: make the patient lie on his back, the knee fully extended; keep the weight of the bedclothes off the foot by a cradle; keep the foot up by means of an ankle strap or a bandage the moment the least tendency to drop the foot is detected, and do not hesitate to apply a plaster if this simpler means does not suffice to maintain the ankle joint in good position; allow walking only when it should be possible without crutches, at first with two sticks and later with one; see that the patient keeps the sole flat on the ground, and, if necessary, retain for a time the plaster splint during walking.

It is better to prevent than to cure, for in bad cases it is a deformity most difficult to cure. This "foot drop" due to the contraction of muscles is different from the talipes equinus that results from muscular spasm, which also, however, is both frequent and difficult to cure.

In many wounded, contractures occur which are out of all proportion to the severity and out of all consonance with the position of the wounds. Clinically they are to be differentiated from cases of paralysis in that by persuasion—sometimes, it is true, rather forcible—the patient can be got to execute slight movements of the toes or even of the foot; from cases of contraction, in that the muscles of the leg retain their size and normal movement, and the intermuscular and subcutaneous connective tissues and the skin are quite sound. The deformity of the foot is more varus and less equinus than in these cases. Under chloroform the foot at once moves normally.

Similar phenomena occur in the upper limb. They seem to belong to the category of functional con-

tractures or traumatic hysteria, and it is often very difficult to differentiate them from organic lesions, from a true neurosis, and even from malingering. But sometimes, in cases in which the patient is certainly not malingering, after an easy correction under chloroform has been effected the deformity recurs immediately after removal of the plaster, in spite of all attempts at suggestion. It is probable that, in these cases, a much earlier manipulation under chloroform, as soon as the earliest signs of the contracture appear, would produce more permanent results.

### B. *Curative Treatment*

1. *True complete Ankyloses.*—It is convenient to consider under this heading all cases of intra-articular bony or firm fibrous ankylosis, as well as of the much rarer extra-articular bony ankylosis. I have seen a good number of such cases treated by ignorant persons by mechanotherapy. And yet it is not at all difficult to appreciate with or without an anæsthetic whether or not movement is absent, to ascertain what has been the nature and degree of severity of the causative arthritis, to verify the existence of bony ankylosis by an X-ray plate. Let us leave, then, these too frequent mistakes in diagnosis to consider the only possible treatment of these cases of complete ankylosis, viz. orthopædic resection, or in some special forms, orthopædic osteotomy. The indications for these operations, subject of course to the restrictions put upon us by the fear of recrudescence of bacterial activity, are exactly as we knew them in civil surgery, of a purely mechanical nature, and quite independent of the pathological cause of the disability.

Hence for ankylosis in flexion and adduction of the hip joint one will have recourse almost exclusively to sub-trochanteric osteotomy. In the case of the other joints resection with the object of getting ankylosis in good position in the lower limb, in the upper limb with the object if possible of regaining at any rate some of the previous range of movement.

Hence in the lower limb one will operate only in cases of ankylosis in bad position ; and in such cases resection of the knee joint, astragalectomy, transverse or cuneiform tarsectomy of the front part of the foot give much better results than does orthopædic apparatus.

In the upper limb I have seen no case of malposition of the shoulder so bad as to require operative interference ; ankylosis nearly always occurs in slight abduction. It is in the case of the elbow joint, almost exclusively of the joints of the upper limb, that operative intervention need be discussed, and I repeat that, in my opinion, except in certain special occupational conditions, the best position for ankylosis is at a right angle, the forearm in supination or halfway between this and pronation. Complete pronation renders a limb ankylosed at a right angle almost useless, and will hence require osteotomy of the radius. On the other hand, it is supination that interferes with the utility of an elbow fixed at an angle of 135 degrees. When the elbow is fixed between 135 degrees of extension and full extension the functional result is deplorable.

As regards fibrous ankylosis of the elbow joint in a bad position it is almost always possible—so much does this joint lend itself to a good grip and leverage —to break down the adhesions by force. In doing

this I have, however, extensively torn a scar involving the skin and muscles at the back of the joint, without thereby interfering with the desired correction of the deformity.

If the ankylosis of the elbow joint is bony, and it is considered that the position requires correction, resection of the joint should be performed ; but where one is aiming at the production of a ne-arthrosis at once stable and possessing a good range of movement, the sub-periosteal orthopædic method of Ollier should be attempted, but not until very late, long after final healing has taken place.

By this method it is certainly possible to obtain a stable movable joint, but this does not result with quite sufficient constancy to make one inclined to attempt it in cases of ankylosis in good position.

In my experience, operation for ankylosis of the wrist joint is hardly ever indicated.

2. *Stiff Joints and Lesions of Muscles and Tendons.*—In cases of stiff joints and the disabilities of tendons and muscle that accompany them, the following methods of treatment possess indications and give excellent results when prescribed for suitable cases :—mechano-therapy, mobilisation, massage, hot baths, and electrical treatment ; but the special indications for each of these methods are not as easy to specify as some writers make out.

(*a*) In the first place, there are varieties of stiff joints in which all these methods are quite useless. Where the range of movement of a joint is mechanically limited, not by any pathological condition inside the joint itself, but by the presence of a particular mass of callus or an inflammatory hyperostosis, we diagnose a " stiff joint," *i.e.* an incomplete ankylosis with

partial retention of mobility. Now in such cases mechanotherapy is just as ineffective as if complete bony ankylosis were present ; the only effective treatment in such cases is the resection of the offending mass of bone wherever this is possible, and when such a course is justified by the functional disability or the presence of serious mal-position. Such a state of affairs is extremely common in badly reduced and mal-united fractures of the lower end of the humerus. These cases, in which the real cause of the disability—deformation of bone—is easily established by radiography, or even on palpation, are characterised on clinical examination by the definite inelastic arrest of passive movement of the joint.

Secondly, mobilisation and massage are harmful in their effects in the presence of inflammation in the tissues ; such inflammation should be considered as contra-indicating the use of these means of treatment even in cases of joint disability that would otherwise benefit from them. Signs of inflammation may be quite absent in the joint itself, but present at some more or less distant part of a neighbouring bone in which union has been complete and the suppuration ceased for a considerable time. Even in such cases massage of the muscles round the bone and daily manipulations of the joint should still be regarded as contra-indicated. Such treatment too often results in a return of pain in the bone and a re-opening of the sinuses. If such a joint be fixed in a good position, and nothing done in the way of manipulation, it will often slowly regain a considerable range of movement of its own accord ; if fixed in bad position, it will be necessary to perform forcible correction followed by immobilisation in good position for three or four weeks.

In order to judge of the necessity for this we must be guided, not by the range of movement that still exists, but by the direction in which such movement is possible—*e.g.* such correction will be necessary in elbow and ankle joints that will not flex to a right angle, in knee joints that cannot be fully extended.

(*b*) The correct treatment for stiff joints is "mobilisation," hot baths and massage constituting important accessory means of treatment. Our aim should be to obtain return of movement, at least in the directions that we have just specified for each joint.

If the joint is fixed in bad position, *i.e.* if it is impossible for the joint to adopt the "position of election for ankylosis," one should, as a general rule, commence by increasing the range of the movement opposite to that which it is desired to increase; in other words, the position of the joint that it is desired to correct or avoid should first be exaggerated, *e.g.* flexion of hip and knee joints, extension of elbow and ankle joints should be increased. After gaining a certain increased range in this direction, one should then proceed to manipulate the joint in the opposite direction, thereby gaining at each manipulation an increase of so many degrees. When the position of election is reached, or as great an increase of range obtained as is possible or desirable, the joint should be immobilised, fixed in this position for a while by some means or other.

The practical realisation of this principle varies, of course, with the particular method of mobilisation adopted, and the choice of this depends on the pathological and clinical variety of the lesion.

The various methods are:—

1. Mobilisation in stages by repeated manipulations.

2. Forcible correction and mobilisation.
3. Correction by successive plasters.

It is often useful to combine two or all of these methods in the treatment of a particular case.

I. Gradual passive mobilisation in successive stages can be carried out in three different ways :—

(1) Manual manipulation performed by the surgeon or masseur.
(2) Passive movement executed by the patient himself.
(3) Mobilisation by mechanically moving apparatus, which, taking firm hold of the joint, forces it through its own range of movement.

This last method, *mechanical mobilisation*, has during the past twenty years come much into vogue, and many special institutions have been furnished with most interesting-looking apparatus by means of which any joint can at will be put through any movement or combination of movements.

But the results in practice have too often fallen short of the hopes and promises of theory. In many cases, in order to avoid pain, or even to save himself trouble, the patient, giving no particular attention to the exercise, keeps working away at the instrument quite mechanically, like a beggar grinding a barrel-organ, in which cases, of course, no improvement occurs. When force becomes necessary, the apparatus, working blindly and mechanically, cannot be regulated with any precision so as to suit the necessities of each particular case; and where the stiffness resists ordinary manual mobilisation, it is much better to have recourse, at any rate for the first stage of treatment, to forcible correction under an anæsthetic.

*Gradual mobilisation by the surgeon* or by a masseur under full supervision—which, in the case of many masseurs, who are no more than presuming empirics, is very necessary—constitutes the method of choice; in adaptability to the varying circumstances and conditions of different cases no other method can rival it.

Such treatment cannot be, should not be, regulated by any arbitrary rules as regards the duration, vigour, or frequency of its application. Long experience is necessary in order to know, from the degree of intensity of the inflammatory reaction, exactly when and in what cases such treatment should be persisted in or suspended.

Pain is almost inevitable whenever, a movement having attained its limit, it is forced further and the pressure maintained for a few seconds or minutes in order to gain ground. No matter how acute this may be, it is not its intensity but its duration that is important and significant. If the pain ceases as soon as the tension on the limb is relaxed (often, however, it ceases earlier), then it should not be regarded as contra-indicating immediate persistence in the mobilisation.

On the other hand, if it lasts beyond the point of relaxation of the force, even if it be less severe, the masseur should defer for the time being all further manipulation, and before recommencing the treatment on the following day he should be most careful to ascertain that no localised points of tenderness to pressure, no swelling or heat, or no redness (as sometimes occurs) are to be detected.

Such signs are those of a recurrence of inflammation in the joint, and according to their intensity it will be necessary either to increase the interval between the

"séances," or to suspend such treatment altogether, and even to resume for a time immobilisation in the position of choice. Often when mobilisation by manipulation is originally decided on, the surgeon has been unable to decide definitely whether or not the joint inflammation has entirely and finally subsided; in such cases treatment supervised and graduated as we have described will very soon settle this doubtful point.

Such treatments under the supervision of the surgeon are necessarily given at intervals, at most once a day; it is, however, most useful to teach the patient in addition exactly how to hold the limb so as to maintain and how by active and passive movements to use it all day long so as to improve even the position gained by the previous manipulation.

I cannot describe all the details of such active and passive movements as are suitable for each particular joint; but several examples will serve to illustrate the general principles, the practical application of which will vary considerably with intelligence and determination of the patient.

Let us take as a short example a case of stiff fingers: the patient can actively flex these very easily and simply by grasping in the palm a cylinder of variable diameter; it is also very easy for him passively to force each finger separately and successively into a position of flexion, and to maintain it there for several minutes.

In the lower limb, in a case of contraction of the tendo Achillis, for example, the patient should plant the foot flat on the ground and execute an active flexion of the knee joint without allowing any elevation of the heel off the ground. This inevitably

results in passive flexion of the ankle joint, rendered possible by the relaxation of the gastrocnemius. This movement, which should be frequently repeated during the course of the day, is the same as that by which in normal walking we prepare to lift the foot from the ground, rolling the foot from heel to toe on the ground and then raising the heel; as soon as the flexibility of the ankle joint increases so that the foot can approach a position at right angles to the leg, walking is the better for the performance of the corrective exercises, carefully supervised to see that the whole extent of the sole is kept flat on the ground at the precise moment when the corresponding limb is vertical and in full extension.

This, then, is an example of the re-establishment and improvement of movement in a joint actually by the exercise of that joint. As a matter of fact many stiff joints become free and supple by the performance of their normal movements by the patient himself on resuming his ordinary work.

This is true as regards limbs that are stiff in a good functional position, and even as regards those in slight mal-position. And I am not sure—not any surer than I am in connection with similar cases in the accidents of civil life—that in these clearly specified conditions mechanotherapy has a good or favourable influence in the case of a wounded man, who goes on for months keeping his limb in one position, and is sometimes in no hurry to be cured.

Quite a different state of things obtains, however, if there be present some considerable degree of deformity or disability—spontaneous correction is then impossible. Before attempting to gain an increase of range of movement of such a stiff joint—or

in some cases leaving it to ankylose completely—the surgeon should always commence by getting it into good position.

II. *Forcible correction*, often useful in order to gain time, is absolutely essential for the initiation of movement in cases in which the immobility is absolute or almost so. It is necessary, in fact, to start by getting a sufficient angular movement to allow the leverage that we are able to exert in manipulations to be efficient.

The operation consists in the forcible manipulation of the joint through the alternate movements of flexion and extension (or, in the case of the shoulder joint, the movements of abduction and then circumduction) in the order we have already specified, and in forcing them to the full extent possible at one sitting, as much time as is necessary being devoted to this purpose.

Judging by the accounts of patients in whom by a trick of the thumb we have suddenly forced into full flexion one or more fingers fixed in extension, it is an extremely painful operation. The pain is extreme, but of short duration; the more stoical of patients can bear it without an anæsthetic, whilst it can often be inflicted suddenly on others by taking them off their guard. It is impossible, however, to perform such an operation without the aid of an anæsthetic in the case of one of the larger joints, where the manipulation will certainly be hard work. In these circumstances ethyl chloride or chloroform should be administered, according as the operation will take a short or long time (the latter is usually the case with the instep, the former with the elbow).

One is often struck, especially where, as in the case

of the fingers, no anæsthetic has been used, by the almost complete absence of pain on movement immediately after the first very painful manipulation is over.

Following the operation, bruising and swelling are usually apparent and well marked, thus proving the rupture of vascular adhesions that we have produced, and that the various crackings in and around the joint heard and felt during the correction led us to anticipate. But real inflammatory reaction is either but slight or altogether absent: the fingers should be left completely free to move, and the same day the patient should be encouraged to work them gently; a larger joint—*e.g.* the elbow or knee joint—should be kept at rest in good position for a day or two compressed by a firm, soft bandage.

If the correction has necessitated violent manipulation, and if for this reason one is led to expect considerable swelling—œdema and bruising—and especially if one suspects the possible occurrence of a revival of latent inflammation, it is best to immobilise the joint in plaster, perhaps for a few days only, perhaps for three or four weeks in cases on which a return of the stiffness, or even possibly definite ankylosis, seems possible, the joint thus being kept in a good position so as to prepare for such an eventuality. Complete immobilisation is in addition, in these circumstances, the best means of arresting the inflammation, and so of preparing the stiff joint for a later and further attempt at correction.

It may be said that forcible correction is successful in almost all cases of stiffness of joints properly so called, even of joints in bad position, and in all cases of peri-articular adhesion of tendons. If, however,

the correction of the position of the limb is not complete, we should have recourse to the following method :—

III. *Correction by a Succession of Plasters.*—Where a joint is fixed in bad position, and especially where it is considered that the inflammation has not quite subsided, correction in stages—an old classical method in orthopædic surgery—often gives excellent results. At each sitting, and without an anæsthetic, as much correction as can be obtained without producing pain is maintained either by manual pressure or else by elastic traction, until the joint is immobilised in plaster in this new position. In this way the fibrous and muscular elements concerned in the contracture are subjected to a continuous tension, *e.g.* the extensors of the elbow and ankle joints, the flexors of the knee. These, which would resist a sudden, even violent attempt at full correction gradually relax under this continuous pressure, and the joint thus gains a little of its former range of movement in this particular direction ; at the end of a fortnight a further increase is gained either by the application of a new plaster altogether, or else by cutting the original one at the level of the joint and filling up with new plaster bands the gap thus produced at the angle of the plaster on the side away from which the joint is being moved.

This method of gradual correction by successive plasters may be compared to that obtained by the spring apparatus of Pierre Robin, who has adapted it to the principal axis of movement of each of the joints. This is worn constantly, and in this way a really strong continuous elastic traction is maintained on the contracted tissues. Considering the method of con-

struction of this apparatus, however, I do not think that it will be of much use in the treatment of bad positions of paralytic origin. But certainly it may be used with great benefit in cases of a moderate degree of stiffness, particularly in the correction of a fixed position of talipes equinus.

An apparatus with elastic traction is most useful for maintaining the corrected position.

IV. *Preliminary Operations.*—These include tenotomy, tenoplasty, and sometimes division of ligaments, a description of the technique of which does not fall within the scope of this book. These operations are indicated when in an anæsthetised patient a tight tendon or ligament can be established as the cause of failure to obtain further correction of a deformity, hence the indication for their performance is often apparent only during forcible correction under an anæsthetic.

They are specially indicated in the foot, *e.g.* the division, or better the elongation, of the tendo Achillis for the correction of a fixed position of equinus. But in war surgery unforeseen failures are common ; the sclerosis of the posterior muscles of the calf and of peri-articular fibrous tissues is often very widespread, so that immediate correction often gives an imperfect result, and relapse is not uncommon. There seems to be present in some of these cases an extensive complicated pathological condition comparable, as I have already pointed out, to the ischæmic fibrosis of Volkmann's contracture of the forearm muscles, and it is common knowledge that the operative treatment of this condition involves the freeing and lengthening of many tendons with complicated plastic repair of their sheaths.

The alternative procedure is to shorten the bones which have become too long for the shortened muscles. This result is obtained in the forearm by resection of portions of the shafts of the radius and ulna. In the foot the corresponding operation would consist in complete or partial astragalectomy, a procedure in many cases followed by firm ankylosis in good position.

True arthrodesis is indicated in paralytic drop foot, but this is frequently complicated by the development of permanent contracture in the muscles of the calf similar to that in the cases we have just been describing. If the foot is quite flail, arthrodesis of the sub-astragaloid and mid-tarsal joints should be performed. The ankle joint should be stiffened in addition only if there is complete loss of power below the knee joint.

V. *Accessory Means of Treatment.*—These consist of :—

*Massage* is useful in softening and stimulating the circulation of the tissues about a stiff joint, and in restoring and developing atrophied muscles. For this latter purpose it is more efficacious than electrical stimulation, especially if it be combined with resisted exercises. It is useless in cases of diffuse muscular sclerosis.

*Hot baths*, if the treatment be prolonged, certainly assist in the mobilisations of joints. Whilst in the bath the movements, both active and passive, can be performed with less difficulty over a greater range and with less pain. Practically all hydrotherapeutic centres advertise this method of treatment : no doubt after the war such advertisement will be increased. It may seem surprising to some perhaps that all these places claim that the advantages gained by this

treatment are due to the special minerals of the different waters. Most probably the rôle of the minerals is quite accessory and the benefit is due chiefly to the heat, perhaps to some extent also to physical and chemical phenomena, the existence of which we are just beginning to realise, occurring in these waters. These seem to be at a maximum in the mud of certain hydrotherapeutic centres; as a matter of fact, for a great many years I have held that for non-tuberculous varieties of chronic arthritis with stiffness and mild attacks of inflammation, treatment with mud baths is best at those centres where in addition they have thought of installing departments for massage, mobilisation, and electric treatment.

## CHAPTER V

## THE EFFECT OF MAL-UNITED FRACTURES ON THE ACTION OF NEIGHBOURING JOINTS

I HAVE thought that it would be useful to group together in this chapter certain rudimentary principles with which we are concerned in the study of the normal and pathological mechanics of the bones and joints.

Whenever, after the union of a fracture, the working of a neighbouring joint is interfered with and the range of its movement limited, it is usual to diagnose "ankylosis of the joint." When it is clearly established that the normal range of movement of the joint is definitely limited, such a diagnosis is of course quite correct. This does not, however, necessarily imply that the joint itself has lost anything of its potential former range; as a piece of mechanism it often remains in itself perfectly normal, nevertheless its physiological action has become abnormal; and in order to restore in such a case the previous range of function, the surgeon has to deal not directly with articular structures, but with a pathological condition that is completely extra-articular.

The rationale of such articular disabilities following fractures is really much less difficult to understand

than "mathematico-phobes"—so numerous among medical men—seem to think; these disabilities are due to the displacement *en masse* in any direction of a joint that in itself remains perfectly normal. From this there necessarily results a displacement or change of its field of action which is increased in the direction of the articular displacement, diminished in the opposite direction; and the physiological problem before us is to ascertain in each case in what way such a change will affect the usefulness of the limb.

A joint may be regarded schematically as composed of a fixed rod (in the limbs always the upper bone or bones) with which articulates a lower movable lever. These, like all solid bodies, bear a definite relation to the three primary planes of space :—

(1) The vertical transverse,
(2) The vertical antero-posterior, and
(3) The horizontal.

These are the geometrical terms which correspond to the anatomical :—

(1) The frontal plane,
(2) The sagittal plane,
(3) The horizontal plane.

Since in anatomy the body is always regarded as vertical, the upper limbs hanging in complete supination and the long axis of the foot in the sagittal plane, we must regard this schematic joint that we are about to study as being similarly placed, *i.e.* with the axes of the two levers (the fixed and the movable) both in the sagittal plane, and the transverse axis of the joint between them horizontal. This, then, is the

position of the axes of the schematic limb in repose, the movable lever lying in the position from which it starts its movements, whose range may be measured in degrees, and which we may call flexion and extension in the sagittal plane, adduction and abduction in the frontal plane, rotation in the horizontal plane around the long axis of the limb, which remains vertical.

Now when this joint is displaced in its relation to the rods by a kink or bend occurring in one or other or both of these its axis undergoes a change of plane. From such a displacement *en masse* of the joint itself, unaccompanied by any change in the articular elements or in the actual range of its potential movements, there results a change to new planes of movements of the rods themselves, and the practical question that arises is to determine accurately under what conditions these modifications of the action of the joint limit movement in useful directions, thereby diminishing the functional utility of the affected joint.

I will take as an example the simplest case, that of a hinge joint represented graphically by a transverse bolt at right angles to the two articulating rods, one mobile the other stationary. Using the arbitrary positions in space that we have adopted, we see that this joint possesses but the movements of flexion and extension. It is the type of the knee and elbow joints.

The most complicated form of joint, from the point of view of planes of movement—the ball-and-socket joint—possesses movements in every direction, including that of rotation. Of this form the hip joint is the type ; we will study it later, especially in its relation to the movement of rotation and the analogous movements of pronation and supination.

### A. The Effect of Mal-union on Hinge Joints

Suppose A B C to be a hinge joint, with C B fixed and movement of A B round B taking place forwards only. The point A turning round the point B describes the circumference of a semicircle, ending by becoming superimposed on the point C, having passed through 180°.

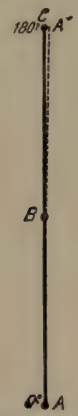



Fig. 101.

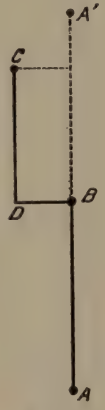



Fig. 102.




Fig. 103.

These two lines C B and A B determine a plane in which this movement of A B takes place. Let us regard this plane as coinciding with the sagittal plane of the body, and then see what takes place when the joint is displaced *en masse* by a kinking of B C. First in the frontal plane, second in the sagittal plane, and third in the horizontal plane. From the study of these the consequences may be readily deduced when the bending of B C takes place not in one but in simultaneous combinations of these three planes.

(*a*) *Transverse Displacement of the Joint* or dis-

placement in the axis of the joint itself by angulation in the frontal plane of the fixed rod B C at the point D, forming either a right angle (fig. 102) or an obtuse angle (fig. 103).

Displaced thus, though unchanged in itself, the joint has lost its former axis with reference to the fixed rod C D. Its plane of movement will always be sagittal, but will now correspond to the line A B and no longer to the line C D. The super-position of A and C is now no longer possible; the point A will always be separated from C by a distance equal to that of D B. Hence we have displaced by this distance inward or outwards, to the right or to the left, the plane of movement of the joint, and whenever A B is flexed to 180° the point A will coincide with the point A′ along the prolongation of the line A B.

Where D B is oblique and not at right angles to C D, the amount of displacement of the plane of joint action will correspond to the projection D H.

The amount of this displacement is independent of the distance from the joint of the point D of bending, independent also of the length of the movable lever.

The range of movement—flexion—possible also remains unchanged, as the lever A B can still pass through 180° to take the position B A′.

In normal anatomy one sees this phenomenon exemplified, in relation to flexion and extension of the hip joint, in the angle that exists between femoral shaft and femoral neck.

Here the neck is doubly oblique, and the plane of the displacement correspondingly so, but the mechanical principle remains the same. The movements of flexion and extension of the shaft takes place not in the sagittal plane of the femoral head, but in a

sagittal plane some distance external to it : this does not at all affect the relative range of flexion and extension of this joint, but other things being equal and in accordance with a mechanism that I shall describe for sagittal displacements, it adds to the field of adduction at the expense of that of abduction.

In the pathological condition of fractures a similar phenomenon occurs in those transverse displacements, in the extreme form of which the lower fragment slides up to lie along one or other side of the upper ; the longitudinal axis of this lower fragment is thus displaced sideways to the extent of its own thickness ; an analogous but rare state of affairs arises when in a double fracture the middle fragment lies more or less obliquely, so that the whole doubly bent lever becomes bayonet-shaped (fig. 104).

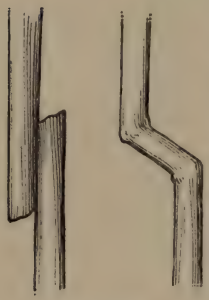


Fig. 104.

In such cases the amount of the displacement is small and of but little practical importance ; what is important in such cases is the shortening that has taken place.

(*b*) *Sagittal Displacement of the Joint, or Displacement parallel to the axis of the Joint.*—Let us refer again to our diagrammatic articulation, let us conceive the fixed limb as bent at D to an obtuse angle $\alpha$, which lies on the side of the two levers opposite to that on which movement of the joint takes place, and the new axis B D as prolonged to B A downwards from the bend at D (fig. 105).

The joint B in itself has undergone no change, but in relation to the axis C D it has moved to the extent of the angle $\alpha$.

The position of A″, the new starting point of the movement (0°), is that where the rod A B lies in a straight line with B D; the end position of movement (180°) is that where B A′ is superimposed on the prolongation of B D, but this remains separated from D C by the angle $\beta$, the supplement of the angle of bending $\alpha$. The range of movement remains unaltered in relation to the real axis B D, but in relation to the axis D C it has increased in one direction and towards one limit of the 180° of range, *i.e.* towards A″, and decreased to a corresponding amount at the other end, *i.e.* towards C′. Now if movement within the field represented by the angle A′ D C is functionally important, and in the field represented by the angle A B A″ of no practical use, the net result is a clear decrease of the range of usefulness of the joint.

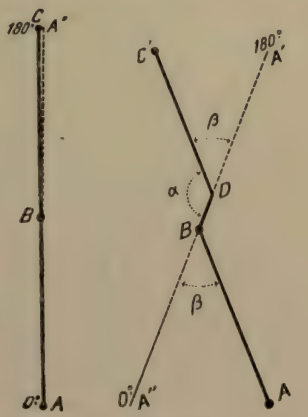


Fig. 105.

This loss is directly proportionate to the distance which still separates the free extremities of the two articulating rods when movement towards each other has come to an end. Hence it is greater the nearer the bend or kink is to the point of articulation.

With the angle C D A′ equal in both, the triangles C D A′ are similar; hence the longer the side C D, the longer also in proportion will be the side C A′ (fig. 106).

This geometrical diagram may be applied exactly

to our hinge joints, of which the best example is the elbow, when a transverse fracture of the lower extremity of the humerus unites at an angle with persistence of the backward tilting of the lower fragment.

In the elbow, normal flexion has a range something short of 180°; it is limited by contact of the soft parts of the forearm and arm. Functionally, however,

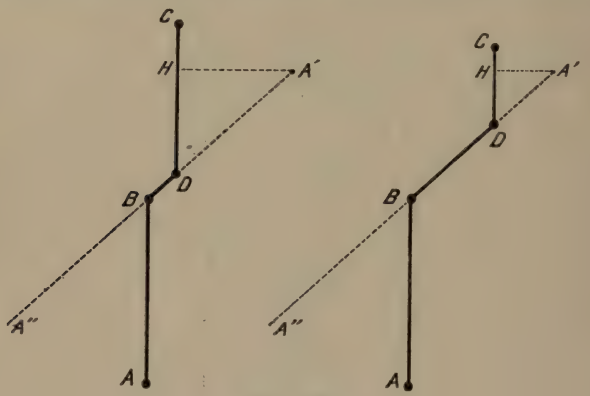



Fig. 106.

flexion should be regarded as complete only when the patient can scratch the front of the shoulder with the tips of his fingers; if the flexion falls short of this, we should diagnose a limitation of the full functional capacity of the joint, and technically the condition becomes one of ankylosis. The joint itself, however, remains quite intact and normal, but its movements, still of a potentially normal amplitude, have lost some of their functional usefulness, which exists only in relation to the long axis of the humerus; they are increased in the direction of hyperextension of the

joint, an increase of no functional significance whatever ; they are decreased in the direction of flexion—a most prejudicial decrease from the functional point of view. In other words, flexion has been handicapped from the commencement, and by the time movement is complete it has not made up its handicap.

The typical case often met with is that in which, the joint remaining normal in itself, careful clinical examination establishes the existence of a negligible degree of hyperextension. But if because of some additional articular lesion extension also is diminished, that does not of course alter the diminished flexion. The paradoxical condition may even occur in which, the forearm at the full limit of its extension lying in a line with the long axis of the arm, extension although practically normal is yet mechanically diminished (by articular lesion), whilst flexion mechanically normal (unaffected by such articular lesion) yet practically falls short of the normal.

The same thing happens in cases of Colles's fracture of the lower end of the radius, in which union has occurred with persistence of the backward tilting of the lower fragment, giving rise to the so-called " dinner-fork " deformity.

The normal movements of the hinge joint of the wrist take place in the two directions of flexion and extension in relation to the long axis of the forearm ; the point of commencement of both these two movements—the position of zero in the geometrical scale of these two movements—is the position in which the long axis of the hand lies in the direct prolongation of the long axis of the forearm. If, then, the lower fragment has united in a position of backward rotation round the transverse axis of the fracture, *i.e.* slopes

backwards and downwards when the long axis of the hand lies in the line of this fragment of the radius, it will make with that of the forearm itself an obtuse angle open behind ; this constitutes an attitude of extension, the degree of extension being proportionate to the supplementary angle of this obtuse angle ; consequently, unless the wrist joint by an increase in its suppleness extends its normal range of movement, flexion will to a corresponding degree fall short of its normal.

In this fracture, the radius being shortened because of the impaction whilst the ulna retains its full length, it is the rule for the hand to become displaced outwards into abduction ; the range of abduction is thus increased, and that of adduction diminished ; but there is, in addition, a horizontal displacement due to an inclination of the normal axis of the joint. Such will be considered later.

We have described, as regards these displacements, their usual form in each fracture, that of backward tilting of the lower fragment towards the direction of extension of the joint.

Exceptionally in the case of the radius, very rarely in the case of the humerus, union occurs with the lower fragment tilted forwards in the direction of flexion ; in such cases the range of flexion is increased and that of extension diminished.

Such a state of affairs occurs in certain fractures of the lower third of the leg where union has taken place at an obtuse angle open forwards, the lower fragment sloping obliquely downwards and forwards. In such circumstances, with the foot at right angles to the leg and the knee straight it becomes impossible to plant the sole flat on the ground ; when

the femur and upper fragment of tibia are vertical and the heel on the ground, as long as the ankle joint is held at a right angle it is quite impossible for the sole to come into contact with the ground, and the patient has inevitably to walk on the heel unless he resorts to one or two possible methods of compensation, either to flex the knee and then of course the hip (fig. 107), or else to drop the foot into a position of equinus,

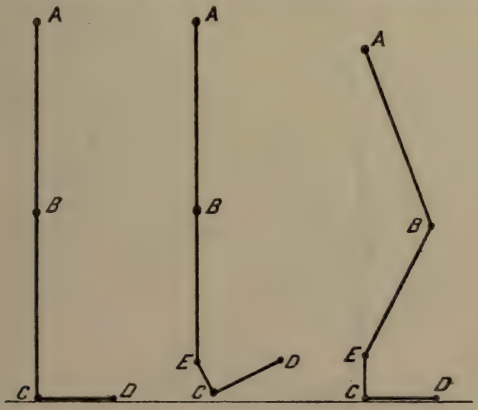



Fig. 107.

the latter method, however, limiting to a corresponding degree the natural rolling of the sole of the foot on the ground during walking.

Union in the opposite direction, the lower fragment obliquely sloping downwards and backwards, sometimes happens, in which case, when the foot is at right angles to the leg and the fore part of the sole on the ground, the heel remains in the air and the foot in a position of equinus, although the range of flexion of the ankle joint still remains normal. Slight cases of this disability in the absence of any articular

lesion gradually develop an increased range of flexion of the foot, which thus compensates for the limitation of flexion we have just described. In severe cases either the patient has to walk on the fore part of the foot, which, unless compensated for by the existence of some shortening of the limb, is most inconvenient and awkward, or else he develops a progressive hyper-extension

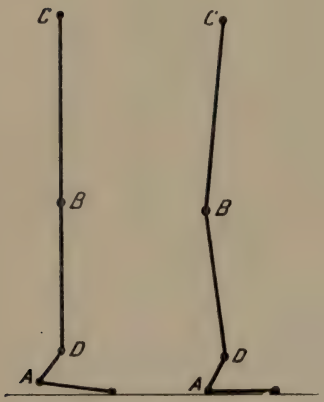



Fig. 108.

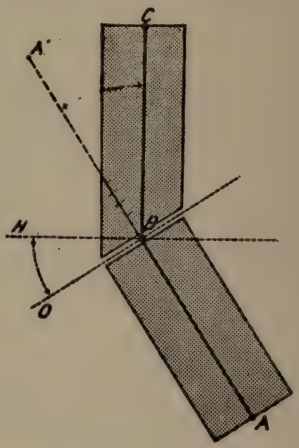



Fig. 109.

of the knee joint, which, if he persists in walking with the sole flat on the ground, in the end becomes a real compensatory genu recurvatum (fig. 108).

(*c*) *Horizontal displacement* by an abnormal inclination of the axis of the joint.

The joint A B C is viewed from the front and represented in its breadth so as to show the obliquity of the axis; the lever A B must always move at right angles to this axis, hence, this axis being oblique, it moves obliquely in relation to the bar B C. The

plane of movement hence is no longer sagittal, and on flexion the point A comes to lie at the point A′ away from C on the side opposite to that to which the obliquity of the articular axis has displaced the free end A of the lever. The angle of deviation of the lever A′ B C is equal to the angle of deviation of the articular axis H B O. The absolute amplitude of the displacement (A′ C) depends on the length of the lever (fig. 109).

This case is not, then, an example of a simple angulation of the bone, but that of an elongation of one side of the fixed bone lever, the other side retaining its original length. Such a state of affairs occurs in supra-condylar fractures of the humerus united in varus ; in such, flexion of the elbow joint, often of normal range, carries the hand well to the outer side of the shoulder, and the hand approaches the mouth only by a combination of abduction with internal rotation.

## B. The Effects of the Mal-union of Fractures on Ball-and-socket Joints

The hip joint is an example of a ball-and-socket joint which not only allows of movement in all directions, but also permits, by an association or combination of these various movements following one another in rapid succession, the further complex movement of circumduction.

(*a*) By reason of the angle that exists between the femoral neck and the femoral shaft the hip joint is, so to speak, displaced inwards ; and since the neck of the femur slopes downwards, outwards, and slightly forwards, the effect of this displacement is correspondingly complex.

The mechanism of this joint may be easily understood if one considers the movement that takes place in each plane as the movement of a hinge joint. As these planes are, for flexion and extension the frontal plane, and for adduction and abduction the sagittal, one will readily comprehend that this natural displacement of the joint places a slight handicap on

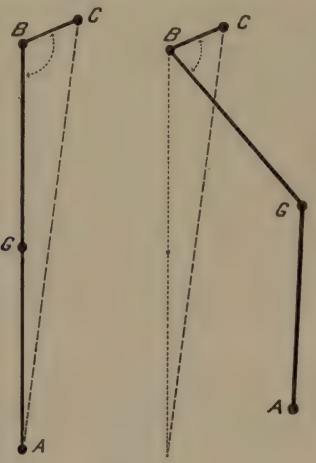



Fig. 110.

flexion—normally so important a movement of the joint—and a great handicap on adduction.

Any decrease, then, in the femoral angle at B will displace the shaft further into adduction, consequently will diminish the range of abduction. Every increase in this angle will have the converse effect (fig. 110).

(*b*) As regards rotation, let us commence by studying its effects in the case of a straight lever.

Suppose we erect a vertical axle rotating on pivots

at its two ends, one of which rests on the ground. Regarding this as representing a human limb, and as standing in the sagittal plane, let us fix to each end of it half a crossbar, each of which also occupies this plane, so that the whole (leaving out of consideration for the moment the femoral angle) represents a lower limb, and the lower half crossbar, resting on the ground, the foot.

Suppose now we cut this axle across at any point between the level of its two crossbars and rotate the lower segment a slight distance round its vertical axis and then rejoin it to the upper in this new position; now whenever the upper crossbar lies in the sagittal plane at the position of 0°, the lower will make with it an angle proportional to the amount of the rotation either inwards or outwards, and in whatever direction and to whatever extent the whole be now rotated, this constant angle between the readings of the degrees of rotation of the two crossbars will remain.

Such a condition as is here represented sometimes actually occurs in fractures of the femoral shaft that have united with but little or no overlapping, but in which some passive external rotation of the lower fragment has been allowed to persist uncorrected. If in such a case the amount of internal rotation possible at the hip joint still allows the long axis of the foot to occupy a plane a little internal to the sagittal, the functional disability that results is of little practical importance; even where the ability to rotate the leg and foot inwards is lost—in other words, where the long axis of the foot can just reach without passing the sagittal plane—the disability remains still practically negligible. In extreme cases, however, in which the long axis of the foot, with as full internal rotation

at the hip joint as possible, fails to reach the sagittal plane, the functional result is one of grave disability. In the first case the displacement of the lower fragment, and hence of the leg and foot, into a position of external rotation is less than the normal amount of full internal rotation at the hip joint; in the second case these two—the external rotation at the seat of fracture and the full normal internal rotation at the hip joint—are equal; in the third case the latter is less than the former, and a mathematician would say that the amount of internal rotation was a negative quantity.

(*c*) So simple and uncomplicated a displacement as we have here used as an example occurs but rarely; the displacement is usually a much more complex one, and takes place in all three of the primary planes.

Other things being equal, the functional consequence of such a displacement in rotation does not vary with the height of the mal-union; on the other hand, the higher up the femoral shaft towards the hip joint union with angulation takes place, the more serious the limitation of the range of abduction and adduction, and such angulation is the more likely to occur the higher the seat of fracture. The extreme cases of such displacement with angulation are usually sub-trochanteric fractures.

If such fractures be left to themselves and neglected, without considering for the moment the element of the deformity due to the overlapping of the fragments, the shaft will be found to unite at an angle in the following manner: the upper fragment becomes flexed and considerably abducted, and slightly rotated outwards; below it the lower fragment falls passively into

a position of external rotation, and sometimes of adduction as well. That is to say, that on the occurrence of union the fragments will form a considerable angle, open inwards, and when the limb comes to hang vertically, parallel to its fellow, as long as the pelvis is kept symmetrical as regards the three planes of space and the upper fragment like that of the opposite side occupies the sagittal plane, the lower fragment of the femur (and consequently also the leg and foot) is in a fixed position of adduction and external rotation, and sometimes too in slight extension.

If the pelvis remained immobilised one can easily see that such a displacement would result in the limitation or total suppression of the range of abduction and of internal rotation. These movements should be regarded as non-existent when the axis of the limb in the case of abduction, the point of the foot in the case of internal rotation, fails to reach a vertical line passing through the head of the femur. Sometimes even such a mal-union affects the range of adduction, a disability which cannot be rectified except by compensatory tilting of the pelvis.

It is by a process of pelvic tilting, similar to that occurring in cases of ankylosis of the hip joint in malposition, that compensation for such limitation of the range of these movements is brought about, elevation of the corresponding side of the pelvis in the case of the adduction of the limb, rotation towards the sound side in the case of the external rotation. Hence will be readily understood the functional gravity of these cases in which not only is there absolute loss of abduction, but even negative abduction, *i.e.* persistence of adduction of the limb when abduction at the hip

joint has reached its limit. Correction of such adduction can be brought about only by a tilting of the pelvis, a procedure that merely adds an apparent shortening to the real shortening already existing, and always considerable in such cases.

(*d*) Such are the mechanical consequences of malunion of fractures of the shaft of the femur regarded from the point of view of the movements imparted to the lower limb from the hip joint. Let us now study those of fractures of the femoral neck, *i.e.* of the part of the femoral lever that lies proximal to its normally existing angle. I have already shown how the diminution of the femoral angle (a rare condition) affects the range of abduction and adduction.

In cases of extra-capsular fracture of the neck with impaction another variety of displacement of the lower fragment occurs, that of rotation with change of relation between the axis of the great trochanter (and hence of the femoral shaft) and that of the femoral neck.

If one looks perpendicularly downwards on to the upper end of a normal femur there will be seen a bar of bone expanded at its two ends, one forming the femoral head, the other continuous with the femoral shaft; this is represented in the diagram (fig. 112) as a straight linear axis.

In extra-capsular fractures the neck becomes impacted into the posterior part of the great trochanter; the posterior surface of the neck thus becomes shorter than the anterior, so that the cervico-trochanteric axis becomes concave backwards, as represented in diagram 112—a curved axis.

Let us now consider the mechanical results of this change. The movement of rotation of the femoro-

tibial lever does not take place round the longitudinal axis of this lever, but describes an inverted cone around the imaginary line passing from the head of the femur to the point of the heel ; that is to say, that rotation on the heel corresponds to a movement of the neck around the head, the great trochanter describing in a horizontal plane the circumference of a circle of which the neck forms the radius ; the position of commencement of the movement—the 0° of the scale of rotation—should be considered as lying a little in front of the frontal plane passing through the femoral head, since in the unrotated position—the long axis of the limb being in the sagittal plane—the neck slopes obliquely downwards, outwards, and forwards. During internal rotation of the limb the great trochanter moves inwards and forwards from this point, conversely during rotation outwards it passes outwards and backwards (fig. 111).

Let us now conceive the neck of the femur as bent to form an obtuse angle open backwards ; this will, then, place the great trochanter behind the prolongation outwards of the femoral head. This means that when the articulating end of the lever is in a position midway between internal and external rotation—the 0° of the scale of rotation—its free lower extremity is displaced into external rotation. Hence in proportion to the amount of this displacement the range of external rotation is increased at the expense of that of internal rotation, which is thus diminished, suppressed altogether, or even becomes a negative quantity.

(*e*) *The effects of mal-united fractures of the humerus on the range of movements of the shoulder joint* are from the practical point of view of but little importance.

In connection with such cases of mal-union of humeral fractures, which of course are far from uncommon, it is obvious that :—




Fig. 111.

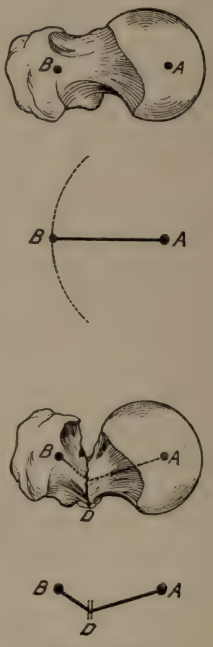



Fig. 112.

(1) Union with acute angulation of the humeral shaft outwards (a frequent variety) and inwards will diminish respectively the ranges of abduction and of adduction.

(2) Union with acute angulation forwards and

backwards will diminish respectively the ranges of flexion and extension.

(3) Union with rotation of the lower fragment in one direction around its longitudinal axis will diminish the range of rotation of the shoulder joint in the opposite direction.

All these disabilities, however, on account of the compensatory movements of the scapula that come into play, have but little functional significance, and are on the whole negligible.

If the scapula be fixed quite firmly and the humerus moved through its range of pure abduction in the frontal plane, this will be found to stop short before the arm reaches the horizontal; but when the movements of the scapula are no longer restricted, this bone tilts and so allows the humerus to reach—and even in young people to pass beyond—the vertical position. As there is normally no interference with this free range of movement of the scapula—the clavicle does not in the least restrict its power of increasing the range of movements of the shoulder joint—it will be readily understood that the loss of some degrees of abduction at the shoulder joint becomes hardly appreciable. The same applies with equal truth in the case of the movements of flexion and extension of the arm.

(*f*) *Mal-union of the Radius and Ulna resulting in limitation of the range of supination.*—Without entering into a full discussion of the details of the question—still a vexed question—of the movements of pronation and supination, we may say that the movement of pronation from the position of full supination consists of a rotation around its vertical axis of the upper end of the radius on the capitellar surface of

the external humeral epicondyle, whilst at the same time the lower radial extremity describes a semicircle from without inwards round the ulna (which, however, also undergoes a movement of its own).

In cases of complete fracture of both bones the instinctive position assumed by the patient if left to himself is one of slight flexion of the elbow joint, with the palm of the hand resting either on the bed alongside the body (the hand being in complete pronation) or else on the abdomen (with the hand in semi-pronation). Now the upper fragments of the two bones remain fixed in supination, hence the movement of pronation has taken place at the site of fracture and not at the elbow joint. If, then, this is not attended to, union of the bones will take place in such a position, and the mechanical result will be diminution or suppression of the range of supination according as the lower fragments have been kept in a position of partial or full pronation compared to the full supination of the upper.

A similar result is liable to follow fractures of the radius alone, and in these conditions an accompanying non-union of the ulna would rather serve to lessen the functional disability. It would allow of freer movement of the lower end of the ulna, which could thus rotate, instead of the lower end of the radius, whose semicircular range has been either diminished or altogether suppressed.

It must be understood that we are dealing here only with the results of this particular form of mal-union—with fixed pronation of the lower fragment—and not with the other varieties of mal-union of the bones of the forearm, angulation, shortening of the radius, the blocking up of the interosseous space by excessive

callus, or the occurrence of synostosis ; the practical conclusion to be drawn is that fractures of the forearm should be treated by immobilisation in supination, and not, as has been so often advised, in pronation or even in semi-pronation. In the gunshot fractures of the present war with extensive wounds and infective complications this is not always possible, but it is the goal at which we should aim.

## Practical Conclusions

I have written this chapter, despite the dryness of its geometrical examples, because it seems to me to convey a lesson of great practical importance.

In the first place, I have endeavoured to show in the course of this chapter what care and attention we should devote to the correction of the displacements, active and passive, of the lower fragments of fractures ; pronation of the hand and wrist ; outward rotation of the leg ; backward displacement of the lower extremities of the humerus and tibia ; angulation in fractures of the femur.

And when we meet with a case in which such a mal-union has taken place, it is important that we should recognise its mechanical significance and not go on treating the limb by perfectly useless manipulation or mechanotherapy. Massage, mobilisation, heat, baths, electricity—all constitute the veriest waste of time both for the surgeon and, what is worse, for the patient. There is nothing wrong with the joint itself, and the muscles are impotent to overcome the disability.

Yet I have seen many such cases treated for long periods by these means, which are from the very nature

of the lesion useless, and all for the lack of careful clinical examination and accurate interpretation of an X-ray plate.

According to the importance of the functional disability in these cases, either leave them alone or perform osteotomy : the only treatment of the least use is to correct the axis of the bony lever. As to the exact nature of the deformity and of the correction required, their recognition will depend, in each particular case, on a knowledge of the phenomena we have described in this chapter.

## CHAPTER VI

## SOME MEDICO-LEGAL CONSIDERATIONS

The lesions studied in this book have in the majority of cases been such as to render necessary either the patient's final discharge from the army, or at least a very prolonged period of convalescence, or his re-classification into some other branch of the service. In this connection there arise medico-legal questions exactly similar to those that have to be decided in our expert medical evidence in connection with the accidents of civil life ; questions that are often most complex, concerning which military law has not so far been very definite, and in which it will prove useful to compare the military rules with the results of arbitration in civil cases.

### I. Methods of Disposal of the Wounded after Cure

When a patient has been cured of his wounds, the chief medical officer of the hospital has to decide definitely whether :—

In cases where he considers that the patient will on the expiry of his leave be fit to rejoin his depot and finally proceed to the front, to grant the usual period of seven days' sick furlough.

Or, in cases where he considers one of the following courses necessary, to send the patient to a hospital depot where sits a special medical board :—

(1) The patient is fit to remain in the actual fighting forces, but possesses a special partial disability which will necessitate

(*a*) his employment on some special duty with his unit,
(*b*) his reclassification into some other branch of the combatant forces.

(2) The patient is unfit for a combatant unit, but fit for duty in one of the auxiliary services.

(3) The patient is unfit for any service, and should be proposed for

(*a*) discharge with a pension where his incapacity is 60 per cent. or over,
(*b*) discharge with or without a gratuity where his incapacity is below 60 per cent.

(4) It is impossible as yet to classify the patient into one of these categories : time is necessary to ascertain what his final condition is going to be. In such cases there will be proposed, according to the period anticipated as necessary,

(*a*) a period of convalescent furlough,
(*b*) a temporary discharge from the army.

In practice, according to the *Regulations of the Army Medical Service of the Interior* (8th edition, April 1914, p. 252 and following), such suggestions for disposal of the patient must be entered on his medical examination certificate by the medical officer in charge of the case or of the hospital in which the wounded man

has been treated. In actual war, however, medical officers have for the most part contented themselves with indicating and assigning the patients to these classes on the clinical history sheet on which they describe the condition of the patient on his discharge from hospital; they should, however (and several circulars have been sent round calling attention to this), fill in the form dealing with pensions and gratuities.

In cases where it is proposed to transfer the patient to some other branch of the combatant service, or into one of the auxiliary services, or to grant convalescent leave, it is necessary to take into consideration very many different factors; these have been specified in special circulars, as they could not be all enumerated in the regulations. Special care and judgment is necessary in each individual case to determine, for example, that a man obviously unfit, at any rate for some considerable time, to carry a pack because of the presence of a scar on his back, is nevertheless able to fulfil certain other duties of the infantryman; that a man quite unfitted for marching because of a scar adherent to his tibia that has been involved in the inflammation, may be useful in the artillery, cavalry, air services, or in a munition factory.

All this depends at once on the present certified state of the lesion, on the nature of the corresponding functional disability, on the patient's previous occupation, on his special physical and mental capabilities. It has been laid down as a general rule—I shall return later to a discussion of this point—that in estimating the percentage of incapacity, the expert should pay no attention to the previous occupation of the patient

(*Regulations*, p. 276, X); but I hold that he should take it into consideration and regard it as important, especially in distinguishing men likely to be useful in the combatant or in the auxiliary services.

Such being the general principles, some remarks as regards special points will perhaps be useful.

## II. When should the Patient be regarded as Cured ?

As regard convalescent leave and temporary discharge, it was not long before practical difficulties arose, especially in cases of peripheral nerve lesions—with which we are not concerned here—and of chronic osteomyelitis, such as we have been occupied with in this book.

At what moment can one say that the lesion justifies one of these proposals ?

Until recently the general instructions seemed to be to keep all patients with chronic sinuses in hospital until a complete cure was obtained, *i.e.* until the wound had completely healed.

But a little knowledge and experience of osteomyelitis serves to show that complete healing of the lesion often takes a very long time, that it often entails delays which cannot be foreseen, during which a small sinus persists, requiring occasional dressing and resulting in the discharge sometimes daily, sometimes only occasionally, of a few drops of pus. We know also that complete healing is not necessarily final, that late formation, even after months or years of apparent cure, of sinuses and even of actual abscesses, is not at all a rare occurrence.

In cases where clinical and radiographic examination show the existence of sequestra, or of a focus of

caries, or of a cavity in the bone with overhanging walls, the performance of an adequate operation should not be delayed.

If none of these conditions exist, that is to say, if there be no indication for operation, the patient should be discharged if in addition to the sinus there be present a lesion that definitely renders him unfit for service; convalescent leave should be granted in cases in which this second condition is not fulfilled.

This condition depends on the functional state of the limb, the presence of shortening, of mal-union of the fracture, and upon the amount of free movement in and the position of the neighbouring joints. The expert should then judge whether or not such a state justifies transference to one of the auxiliary services, whether reclassification in the combatant services or temporary or final discharge best fits the case.

In cases of persistent sinus due to osteitis of the shaft of a long bone, this by itself is not sufficient justification for definite discharge; prolonged convalescence under the supervision of a surgeon with experience of the surgery of bone lesions would be a suitable method of disposal.

For months I maintained this opinion without being successful in bringing about a change. At the convalescent depots the smallest crust used to be scraped off, and if under it was found a point of bleeding granulation the case was sent back to hospital as insufficiently cured.

For some time now, thanks to the very precise instructions of the inspecting director of medical services of Paris, sound surgical teaching has triumphed.

Where an operation is indicated (and it is well for the advice of a surgeon of reputation to be obtained) it should be performed as soon as possible.

Where no operation is indicated, no time should be lost in adopting one or other of the courses enumerated above, so that hospitals may not be uselessly encumbered with wounded who are able to work, getting their sinuses dressed once or twice a week at the military hospital nearest to their place of residence. They can be admitted again to hospital if a return of the inflammation necessitates any further surgical treatment.

This is how in the past we have been accustomed to treat all our civil cases of osteomyelitis; there is no reason for refusing to use this method in military cases: except in a few cases—and in these retention in hospital is of course the patient's due—this is what the patient himself desires above all things; it is much more economic to the State, and much more favourable to the recuperation of the patient.

I do not know whether or not such a method is employed in all the military districts of the interior; it seems to me that it should be in general use, and that is why I describe here what is actually in operation in Paris.

## III. Pensions and Gratuities

According to the *Regulations of the Medical Service of the Army of the Interior* (vol. lxxx., 6th edition, issued up to the 1st April 1914), diseases and disabilities attributable to military services are of two varieties :—

(1) Those whose severity justifies discharge from the army with a pension ;[1] an official list of these is recounted.

(2) Those which, resulting in a disability or incapacity of a less severe nature—not found or mentioned in the above official list—justify discharge No. 1 with a gratuity, that may if necessary be repeated.

At once medical men noticed a very singular detail in these regulations : only certificates for discharge with a pension should mention the incurability of the lesion ; certificates for discharge No. 1 " must never certify incurability."

This conception of incurability has doubtless been the cause of many of the curious criticisms directed against the " Table of classification of wounds entitling patients to a pension in accordance with the various categories fixed by the Laws of the 11th and 18th April 1831."

Thus to have made use of the numbers of the old classification in connection with the medicine and surgery of 1914, the unfortunate but anonymous persons responsible for these regulations must have been still under the influence of the state of medical and surgical knowledge in 1831.

They must have been influenced too by the administrative necessity of not submitting to the alternative of the " renewable gratuity " in cases of discharge No. 1. For example, we find classed together into

[1] The Law of 1831 was concerned with the loss of a limb or some similar incapacity. A little after the commencement of the present war supplementary instructions specified that a pension—the original difference between this and gratuity has been maintained—was to be granted in all cases in which the disability resulted in a loss of at least 60 per cent. of the functional capacity. Hence the publication of a *Handbook of Guidance and Reference* that I shall deal with later, and which all civil experts would do well to procure.

the sixth and last category, amputation of the great toe with its metatarsal bone, of two toes with their metatarsal bones, that of the five toes, ankylosis of the knee, elbow, and hip joints in good position, and ankylosis of the shoulder. The incapacity is regarded as identical in the case of amputation of the thumb with or without its metacarpal bone—a point I certainly consider as contestable. And is it at all reasonable to establish even in the sixth category an identity of incapacity between these lesions and that due to the " loss of function of a limb " merely in order to keep within the classification of the Law of 1831 ?

All this results in untruthful and quite inadmissible assertions, for in the certificate of incurability in the case of discharge with a pension the medical officer has (p. 261 of the *Regulations*) to declare that the lesion is grave and incurable, and that it renders the patient not only unfit for service, but also unfit to earn his living.

And I have seen certificates in which medical men have not hesitated, merely to keep within the regulations, to certify that ankylosis of the elbow or shoulder makes a man unfit to earn his living. Take this nomenclature and see in how many cases it is in accordance with established facts—in but very few—and I may add, that in accordance with its provisions a larger pension goes to those with amputation of the thigh (third class) than to hemiplegic lunatics, to those suffering from general paralysis in the stage of incontinence (fourth class), or even in the stage of imbecility (fifth class).

Let us now pass on and leave these defects in classification ; as a matter of fact, in the early days of the war the instructions relative to pensions and discharges

were very badly drafted, and those responsible for them seem to have been very largely out of touch with the knowledge and experience gained by expert medical witnesses since the passing of the Workmen's Compensation Acts ; and what real difference is there between the two sets of cases, civil and military ?

And especially when one considered the appalling number of the disabled did the necessity appear absolute for the authorities to provide medical officers with a set of instructions at once more precise and up to date ; hence the order of 24th March 1915, and the appearance of a *Handbook of Guidance and Reference*, whose author, although anonymous, has certainly proved himself very competent.

This Handbook besides pretends to be no more than a guide, for the author holds that the after-results of accidents—even the accidents of warfare—are quite incapable of classification into any absolute scheme, no matter how comprehensive or exhaustive. There are of course certain typical cases in which the incapacity, always identical, can be estimated, so to speak, almost automatically ; but in nearly all cases an accurate estimation of the degree of incapacity is possible only by an expert clinical examination that perforce has to take into account a great many factors of the utmost variability in different cases.

The object of this little book is primarily to establish different classes of gratuities corresponding to percentages of functional incapacity to compensate for those lesions that are not from the outset sufficiently serious and disabling to justify the patient's discharge on a permanent pension ; those valuations of gratuity are based on the awards of the civil courts in cases of compensation for the accidents of employees.

Instead of following too closely, however, the example of civil arbitration—in which the incapacity for work is estimated at the moment of the examination and report, but remains liable to revision for better or for worse for a period of three years—the military authorities have retained their original division of methods of compensation into pensions and gratuities.

For cases of incurable incapacity amounting to less than 60 per cent. a new class of permanent gratuities has been established; the reason for this further class in addition to pensions is not altogether clear; what matters is the permanence and not the percentage of the incapacity.

For cases of incapacity liable to undergo in time a change of extent or severity the original temporary gratuity has been retained. It is obvious that this is right, because with our usual electoral methods procedures of revision properly so called would only give rise to difficulties that can be easily foreseen.

The writer of this Handbook takes care to declare in the most absolute manner that his work is not intended "In the very least to modify the scale of gravity of wounds or of incapacity decided on by the administrative authorities of 23rd July 1887, and expounded in the Instructions of 23rd July 1887 and of 23rd March 1897." And he concludes that medical experts will continue to make use until further orders of this scale of 23rd July 1887 when dealing with such severe and incurable disabilities as warrant the patient's discharge from the army on pension." They make use of this Handbook and consult the percentages that it suggests for disabilities and illnesses incapable of being regarded as severe and incurable in all their

aspects, and so of fulfilling the conditions laid down by the Law of 11th April 1831 as alone justifying permanent discharge from the army.

The Instructions of the Handbook then, with the single exception that we have alluded to as regards the permanent gratuity, are perfectly clear and definite. But they are certainly rendered less valuable and efficient by the statement "that it is not intended in the least to modify the former scale of gravity, etc."

However, it does modify it, and it is good that it has done so in such a way as to eliminate those absurdities, to some of which I have already called attention. But the consequence of this attempt of the authorities to save appearances is that a considerable number of doctors still continue to refer to this faulty nomenclature, that many discharges continue to be described as belonging to "categories," in a typical one of which disarticulation of the shoulder, of the hip, and of the ankle joints are grouped together as of the same order of severity.

Our point of view is surely that of the author of the Handbook, since he attributes to the various amputations a different percentage of incapacity. It would, then, have been better to have cancelled completely the former scale of gravity, since all its numbers reappear in the new.

I believe also that in this new classification it was a mistake to put amputation of the upper extremity above and below the elbow joint into the same category, and also to estimate at 100 per cent. the incapacity of double amputation of the foot. Such do not take into account the functional results obtained by the expert application of artificial limbs.

In this connection I will make reference to a

principle indicated in but a few words in the Guide, but which, in my opinion, deserves a position of prominence.

It is *à propos* of amputation of the lower third of the leg that it refers to cases in which "the stump is healthy, the scar firm and in a good position."

Now this is a remark worthy not only of emphasis but of wide application. In considering the percentage of incapacity in cases of amputation, the quality of the artificial limb to be worn should be an important factor in the decision; one should consider most carefully in each case what variety of artificial limb will be suitable to such conditions as may be present, *e.g.* the particular shape and length of the stump, the position of the scars, the presence of infection of the bone, the existence of tender spots. The length, it might be said, is sufficiently indicated by the naming of the level of the amputation; this is not altogether so, especially in two cases, amputation through the surgical neck of the humerus and sub-trochanteric amputation of the femur are amputations of the arm and leg respectively, yet from the point of view of the future artificial limb they are no better than the corresponding disarticulations, for so short a stump is of but little use either for weight-bearing or for the transmission of movement to the apparatus.

This takes me on to a still more generalised observation, with which I shall end this section.

In reporting on the incapacity resulting from civil accidents we are accustomed to consider as an important element in determining the percentage the former occupation of the injured man. Amputation, for example, does not constitute so great an incapacity

in the case of an accountant as of a navvy. It is a matter for regret that such is not taken into consideration in the case of wounded soldiers about to be discharged, but one should recognise that for various reasons, sentimental, political, and otherwise, this would be difficult to systematise; the public would not understand these differences in the case of soldiers with the same wound—equally "glorious"; such points can be understood only by competent experts.

## IV. The Refusal of Treatment

The medico-legal question that has recently attracted most attention is that of the refusal of the soldier to undergo a certain mode of treatment or to submit to a certain operation.

This question has been dealt with at great length in the political press in connection with a case that a few weeks ago ended in a court-martial. The subject being brought up by one of its members, the Academy of Medicine after quite a long discussion in a secret sitting passed a resolution that I shall quote further on.

I have taken the following account of a case as detailed in a serious daily paper in an article that aimed at being considered witty:—

A man was brought before a court-martial for refusing certain treatment just as though this was a refusal to obey orders, and the journalist made fun of the doctor for applying to a military court instead of using moral suasion and inspiring the patient with confidence.

Had the circumstances really been as stated, the journalist would certainly have been right, and no doctor would disagree with me in saying so, but

unfortunately he wrote carelessly without troubling to verify his facts, for the case was really very different : an obvious malingerer on having an electric shock administered to him suddenly found himself able to stand up and strike the major several blows with his fist : he was tried and condemned for assau t on a superior officer.

This was certainly not a case of court-martial invoked by a doctor for refusal of treatment as if for disobedience of orders.

But has the doctor the right to submit a patient to any form of treatment whatsoever which the patient has not a corresponding right to refuse ? Such is the conclusion that the Academy of Medicine has come to (*Bulletin*, 1916, vol. ii. p. 210) in deciding on the following " order of the day " :—

" In a secret sitting the Academy has adopted the following conclusion concerning the methods of intervention and examination that may become necessary in the diagnosis and treatment of cases in the military medical service :—

" Under the conviction that all measures have been or will be taken to secure for sick and wounded soldiers the competent medical and surgical attendance and treatment to which they are entitled, the Academy, considering the question from a purely medical point of view, considers that sick and wounded soldiers are not justified in withholding their consent to any procedures of clinical investigation necessary for diagnosis, or to any methods of medical or surgical treatment that are in accord with the present state of our knowledge and experience and that are likely to result in cure."

The wording of this seems to me to be poor, for it takes no account of the fact that surgical methods of treatment, though quite in accord with the present state of our knowledge, can and do possess an element of danger, were it only that of the administration of the anæsthetic, that all surgeons are not equally skilful, and that the functional result of an operation

can be anticipated in terms of probability and not of certainty.

I much prefer the official text published in the B. O. B. P. of the 5th April 1915 under the title :—

## Instruction relative to the Courses of Action necessitated by the Refusal by the Soldier of Treatment or Operation recognised as necessary

The Minister has at different times been consulted as to the course of action that should be taken in the case of soldiers on active service or of wounded in hospital who, for various reasons (an imperfect comprehension of their own true interests, wrong-headed wilfulness, or with the intention of prolonging their stay in hospitals, and sometime also in the hope of escaping military service or of obtaining a permanent or larger pension), refuse treatment or operation of such a nature as either to confer immunity against certain diseases or to result in the cure or improvement of their incapacity for work produced by wounds.

Generally speaking, one should in such cases avoid having recourse to any measure of coercion at all. The doctor should try persuasion, explaining to the soldier the object of the proposed procedure, pointing out to him his own best interests and the benefit that he will derive from the treatment or operation to which he is hesitating to submit himself.

Where the refusal, however, is absolute, the solution will vary according to the object and nature of the proposed treatment or operation :—

(1) When in connection with such procedures ordained by law to protect the health both of the individual and of the general public or army, as vaccination against smallpox and typhoid fever, such refusal is inadmissible.

Such treatment should be carried out officially in the interest of the whole army, and the refusal to submit to it treated as similar to a military crime, and justifying disciplinary measures of repression.

(2) When a wounded man refuses a simple and bloodless method of treatment, *e.g.* the different forms of physiotherapy, massage, mechanical manipulation, heat baths, electrotherapy, etc., which, while being quite free from risk are such as to lessen the disability from which he is suffering and to increase his capacity for work, he should be treated as a malingerer who intentionally keeps open or aggravates his wound by refusing treatment so as to limit or

annul his subsequent usefulness as a combatant, or of increasing either his chances or the actual amount of a future pension.

By such conduct he may incur the various disciplinary measures laid down for such misdemeanours without prejudicing the possibility of an ultimate reduction of the percentage of his incapacity for which compensation will be granted similar to that indicated in the following paragraph:—

(3) The right to refuse an open operation with or without an anæsthetic is considered as absolute by the law on account of the fact that every such operation involves a certain risk of death; but the exercise of this formal right carries with it certain responsibilities, *e.g.* exposes the patient to a possible reduction of the future amount of his compensation, especially in the two following cases:—

(*a*) When the operation is a very slight one, especially when it does not necessitate the administration of an anæsthetic, *e.g.* the incision of a superficial abscess, the removal of a quite easily accessible bullet.

(*b*) When the performance of an operation is rendered urgent and necessary beyond all manner of doubt by the occurrence of some complication that is likely to lead to some absolute or serious incapacity, *e.g.* the refusal to allow the enucleation of an injured eye where the onset of sympathetic ophthalmia is feared, the refusal to allow amputation of a gangrenous limb, etc.

In such cases it is of course the duty of the medical man, both as professional adviser and as friend, to explain to the patient that operation forms the only chance of his survival, of his prompt cure, or of diminishing his incapacity, as the case may be.

He should offer to call into consultation one or even more consultants, or finally, and if necessary, propose to transfer him to the surgical centre of the military district.

If, in spite of all this, the patient still persists in refusing, the medical officer will draw up a report which will exactly specify the nature of the operation and the condition that has rendered it necessary, as well as the refusal of the patient, with his motives in refusing. This will be signed by the patient, the doctor in charge of the case, and the officer in charge of the hospital; if the patient refuses to sign, mention of this will be made in the report.

This report will be completed in duplicate, one copy being kept by the officer in charge of the hospital, the other sent to the headquarters of the unit to which the patient belongs.

On discharge of the patient from hospital, or on his return from convalescent leave, two possible cases are to be considered:—

(1) Where the wounded man is still fit for duty as a combatant or in one of the auxiliary services, he will then return to his depot, and will be utilised in accordance with the regulations in force at

the time dealing with the standard of physical fitness until his term of service is up, and then later in the reserve.

(2) Where the wounded man, at the end of his period of service, presents a variable reduction in his capacity for work, or where, on leaving hospital or later, he is considered incapable of further service, in such cases he will be brought before a special discharging board and examined in accordance with the regulations in force, with a view to proposal for discharge with a gratuity or discharge with a pension.

In all cases, in assessing his percentage of reduction of capacity for work, the examining experts, placed in possession of the report as to his refusal of treatment or operation, will specify in the form of a fraction the proportion of such incapacity reducible by the performance of the proposed operation.

The proposals of this board will be recorded, an account being taken of the proportion of the total incapacity due to the refusal of treatment.

A committee of consultants, or, in its absence, a special medical board, will finally pass judgment from the point of view both of the seriousness and of the incurability of the disability, as to the reduction of full capacity for work due directly to the actual wound itself and that resulting from the refusal of treatment or operation.

Hence when a patient refuses treatment an official report should be filled in and signed both by the doctor, who should state the exact nature and aim of the proposed treatment, and declare it to be free from all danger, and also by the patient, who should indicate the reason for his refusal.

The final judgment has to obtain the sanction of the military authorities, but it is obvious that the considered opinion of medical experts will be of the greatest importance in determining two points :—

(1) That from such a refusal directly results a persistence of incapacity the degree of which would be reduced by the treatment.

(2) That the man is a malingerer, or at least that he fears that the treatment, operative or not, would render him fit again for active service.

In case (1), the medical report will follow the lines of

our expert evidence before civil arbitration tribunals: it is pointed out what the actual percentage of incapacity is and what it probably would be after the operation; the tribunal then judges the case in the light of this evidence, usually debiting against the workman the fact of his unwillingness.

Cases of malingering seem at first sight very simple; such may well be so in cases in which the diagnosis is certain; in these cases in the special neurological centres a skilful clinician is generally successful in proving the fraud. All that is then necessary is to fill in a report, giving full details with the proofs in support, and then to return the delinquent into the hands of the military authorities.

But it should be recognised that complicated and difficult cases occur—indeed they are not at all rare—in which the diagnosis remains uncertain, concerning which a definite opinion cannot be pronounced, at least at first.

Putting on one side cases of real traumatic hysteria characterised by contractures and paralyses—such patients are genuinely and sincerely ill, and require to be treated accordingly—and also cases of true retraction of muscles and tendons due to sclerosis, there still remain a whole group of cases of wounds involving or lying close to muscles that become complicated by the occurrence of contractures; in these it is difficult to decide whether they are reflex or assumed.

In cases in which the patient has kept professing his desire to return to the trenches—a thing the general public is far too prone to believe—my impression is, that if this desire were genuine he would soon be successful in achieving the very slight effort

of the will which is all that is necessary to bear the initial pain and to become cured. This effort he does not make, not because he is altogether a malingerer, but at any rate in part because he is really not at all anxious to be discharged from hospital. This is an example of unconscious psychology, or, to make use of the language of modern philosophy, of the psychology of the subconscious mind.

Such a state of affairs most often occurs with wounds affecting the foot. Because of some painful or tender scar, often very insignificant in itself, *e.g.* slight perforating bullet wounds somewhere near the tendo Achillis, the patient begins to walk on the outer edge of the foot. This he continues to do, and the foot becomes fixed in equino-varus by contracture of the calf muscles and the tibialis anticus. There must be in such a condition some material physical basis—so far not successfully accounted for, it is true, for I have seen such cases in which could be provoked clonic spasms like those of Jacksonian epilepsy. But in these cases nothing definite can be made out in the way of sclerosis of muscle, since under an anæsthetic, and even sometimes without an anæsthetic, by taking advantage of a moment of muscular relaxation, complete correction can be obtained without the use of the least amount of force.

But fix such a foot in plaster in the position of valgus for two to three weeks ; immediately on removal of the plaster the contracture will reappear.

Is this malingering, deliberate deceit, or the result of the subconscious mentality of the neuropath who, without perhaps actually confessing it even to himself, prefers to remain where he is ? It is just possible—I think it is even probable—that a tenotomy would

cure this contracture ; but our experience and knowledge of these cases is still not sufficient to warrant our insisting on this treatment.

A very similar position obtains as regards those cases of muscular contracture in which, by some special method of muscle training—in which also no doubt the will plays an important part—the patient is enabled to exhibit the phenomenon of the " snapping joint."

Such cases should not be subjected to court-martial, but are amenable to psychotherapy ; and there exist certain special centres where such psychoneuroses—often of a most difficult and complicated nature—are treated under the direction of competent specialists.

The only way of arriving at an accurate diagnosis of such patients as either refuse treatment or submit to it with a bad grace is to keep them under exact and constant surveillance.

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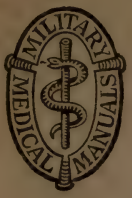
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The other book published by Mme. Athanassio Benisty, which was devoted to the *Clinical Features of Injured Nerves*, explained the method of examination, and the indications which enable one to differentiate the injuries of the peripheral nerves. It is a highly practical guide, which initiates in the diagnosis of nervous lesions those physicians who have not hitherto made a special study of these questions. —This second volume is the necessary complement of the first. It explains the nature of the lesions, their mode of repair, their prognosis, and above all their *treatment*. It provides a series of particularly useful data as to the evolution of nerve-wounds—the opportunities of intervention—and the prognosis of immediate complications or late sequelae.

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The author strives on every page to develop the idea that anatomical conservation must not be confounded with functional conservation. The two things are not so closely allied as is supposed. There is no conservative surgery save where the function is conserved. The essential point of the treatment of diaphysial fractures consists in the early operative disinfection, primary or secondary, by an extensive sub-periosteal removal of fragments, based on exact physiological knowledge, and in conformity with the general method of treating wounds by excision. When this operation has been carefully performed with the aid of the rugine, with the object of separating and retaining the periosteum of all that the surgeon considers should be removed, the fracture must be correctly reduced and the limb immobilized.

For each kind of fracture the author has given various methods of immobilization, and examines in succession : the anatomical peculiarities—the physiological peculiarities—the clinical course —the indications for early treatment—the technical steps of the operations—and the treatment of those who only come under observation at a late period.

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Previous to the present war no stomatologist or surgeon possessed any very extensive experience of this subject. Claude Martin, of Lyons, who perhaps gave more attention to it than anyone else, aimed particularly at the restoration of the occlusion of the teeth, even at the risk of obtaining only fibrous union of the jaw. The authors of the present volume take the contrary view, maintaining that consolidation of the fracture is above all the result to be attained. The authors give a clear account of the various displacements met with in gunshot injuries of the jaw and of the methods of treatment adopted, the latter being very fully illustrated.

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Grounding his remarks on a considerable number of observations, Professor Lagrange arrives at certain conclusions which at many points contradict or complete what we have hitherto believed concerning the fractures of the orbit: for instance, that traumatisms of the skull caused by fire-arms produce, on the vault of the orbit, neither fractures by irradiation nor independent fractures; that serious lesions of the eye may often occur when the projectile has passed at some distance from it. There are, moreover, between the seat of these lesions (due to concussion or contact) on the one hand, and the course of the projectile on the other hand, constant relations which are veritable clinical *laws*, the exposition of which is a highly original feature in this volume.

The book is thus far more than a mere "document," or a collection of notes, though it may appear both; it is, on the contrary, an essay in synthesis, a compendium in the true sense of the word.

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The number of soldiers affected by hysterical disorders is great, and many of them have been immobilized for months in hospital, in the absence of a correct diagnosis and the application of a treatment appropriate to their case. A precise, thoroughly documented work on hysteria, based on the numerous cases observed during two years of war, was therefore a necessity under present conditions. Moreover, it was desirable, after the discussions and the polemics of which this question has been the subject, to inquire whether we ought to return to the old conception, or whether, on the other hand, we might not finally adopt the modern conception which refers hysteria to pithiatism.

This book, then, brings to a focus questions which have been especially debated; it does not appeal exclusively to the neurologist, but to all those who, confronted by paralysis or post-traumatic contractures, convulsive attacks, or deafness provoked by the bursting of shells, have to grapple with the difficulties of diagnosis and ask themselves what treatment should be instituted. In it will be found all the indications which are necessary to the military physician, summarized as concisely as is possible in a few pages and a few illustrations.

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Of all the medical works which have appeared during the war, this is certainly one of the most original, both in form and in matter. It is, at all events, one of the most individual.

The authors have preferred to give only the results of their own experience, and if their conclusions are not always in conformity with those generally accepted, this, as Professor Pierre Marie states in his Preface, is because important advances have been made during the last two years; and of this the publication of this volume is the best evidence.

Thanks to the method of radiographing the convolutions after filling the furrows, which has become sufficiently exact to be of real service to the clinician, the authors have been able to work out a complete and novel cerebral pathology, which presented itself in lamentable abundance in the course of their duties, which enabled them to examine and give continued attention to many thousands of cases of head injuries.

Physicians and surgeons will read these pages with profit. They are pages whose substance is quickly grasped, which are devoid of any display of erudition, and which are accompanied by numerous original illustrations.

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By Assistant-Professor OMBRÉDANNE, of the Faculty of Medicine, Paris, and M. LEDOUX-LEBARD, Director of the Laboratory of Radiology of the Hospitals of Paris. Edited by A. D. REID, C.M.G., M.R.C.S., L.R.C.P., Major (Temp.) R.A.M.C., with a Preface on Extraction of the Globe of the Eye, by Colonel W. T. LISTER, C.M.G. With 225 illustrations in the text and 30 full-page photographs. Price, 10*s.* 6*d.* net. Postage 6*d.* extra.

Though intentionally elementary in appearance, this compendium is in reality a complete treatise concerning the localisation and extraction of projectiles. It appeals to surgeons no less than to radiologists.

It is a summary and statement—and perhaps it is the only summary recently published in French medical literature—of all the progress effected by surgery during the last two and a half years.

MM. Ombrédanne and Ledoux-Lebard have not, however, attempted to describe all the methods in use, whether old or new. They have rightly preferred to make a critical selection, and—after an exposition of all the indispensable principles of radiological physics—they examine, in detail, all those methods which are typical, convenient, exact, rapid, or interesting by reason of their originality: the technique of localisation, the compass, and various adjustments and forms of apparatus. A considerable space is devoted to the explanation of the method of extraction by means of *intermittent control*, in which the complete superiority of radio-surgical collaboration is demonstrated.

Special attention is drawn to the fact that the numerous illustrations contained in this volume (225 illustrations in the text and 30 full-page photographs) are entirely original.

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Dr. Abadie, who, thanks to his past surgical experience and various other circumstances, has been enabled, at all the stations of the army service departments, to weigh the value of methods and results, considers the following problems in this volume, dealing with them in the most vigorous manner:

1. How to decide *what is the best treatment* in the case of penetrating wounds of the abdomen.

2. How to instal the *material organisation* which permits of the application of this treatment; and how to recognize those conditions which prevent its application.

3. How to decide *exactly what to do in each special* case; whether one should perform a radical operation, or a palliative operation, or whether one should resort to medical treatment.

This volume, therefore, considers the penetrating wounds of the abdomen encountered in our armies under the triple aspect of *doctrine, organisation, and technique.*

We may add that it contains nearly 70 illustrations, and the reproductions of sketches specially made by the author, or photographs taken by him.

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Hospital practice had long familiarised us with the vascular wounds of civil practice, and the experiments of the Val-de-Grâce School of Medicine had shewn us what the wounds of the blood-vessels caused by modern projectiles would be in the next war. But in 1914 these data lacked the ratification of extensive practice. Two years have elapsed, and we have henceforth solid foundations on which to establish our treatment. This manual gathers up the lessons of these two years, and erects them into a doctrine.

In a first part, Prof. Sencert examines the wounds of the great vessels in general; in a second part he rapidly surveys the wounds of the vascular trunks in particular, insisting on the problems of operation to which they give rise.

"I should like it to be clearly understood," he concludes, "that the surgery of the blood-vessels is only a particular case of the general surgery of wounds received in war. There is only one war surgery: the immediate operative surgery which we have been learning for the last two years.

"This rule is never more imperative than in the case of vascular wounds. Early operation alone prevents deferred and secondary haemorrhage; early operation alone can prevent the complications which are so peculiarly liable to result from the effusion of blood in the tissues; early operation alone can obviate subsequent complications. Here, as everywhere, the true and useful surgery is a surgery of prophylaxis."

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The authors of this book have sought not to describe this or that piece of apparatus—more or less "new-fangled"—but to explain the anatomical, physiological, practical and technical conditions which an artificial arm or leg *should* fulfil.

It is, if we may so call it, a manual of *applied mechanics* written by physicians, who have constantly kept in mind the anatomical conditions and the professional requirements of the artificial limb.

Required, during the last two years, to examine and equip with appliances hundreds of mutilated soldiers, the authors have been inspired by this guiding idea, that the functional utilisation of an appliance should take precedence of considerations of external form. To endeavour, for æsthetic reasons, to give all subjects the same leg or the same arm is to risk disappointment. The mutilated soldier may have a "show hand" and an every-day hand-implement.

The manufacturer will derive no less profit than the surgeon or the mutilated soldier himself from acquaintance with this compendium, which is a substantial and abundantly illustrated volume. He will find in it a survey and a reasoned criticism of mechanisms which notably display the ingenuity of the makers —from the wooden "peg" of the poor man, together with his "best" leg and foot, to the artificial limb provided with the very latest improvements.

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By H. VINCENT, Medical Inspector of the Army, Member of the Academy of Medicine, and L. MURATET, Superintendent of the Laboratories at the Faculty of Medicine of Bordeaux. Second Edition. Translated and Edited by J. D. ROLLESTON, M.D. With tables and temperature charts. Price, 6*s*. net. Postage 5*d*. extra.

This volume is divided into two parts, the first dealing with the clinical features and the second with the epidemiology and prophylaxis of typhoid fever and paratyphoid fevers A & B. The relative advantages of a restricted and liberal diet are discussed in the chapter on treatment, which also contains a description of serum therapy and vaccine therapy, and general management of the patient.

A full account is to be found of recent progress in the bacteriology and epidemiology of these diseases, considerable space being given to the important question of the carrier in the dissemination of infection.

The excessive frequency of typhoid fever in war time is demonstrated by a sketch of its history from the War of Secession of 1861-1866 down to the present day.

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This, the second of the volumes which Professor Vincent and Dr. Muratet have written for this Series, was planned, like the first, in the laboratory of Val-de-Grâce, and has profited both by the personal experience of the authors and by a mass of recorded data which the latter years of warfare have very greatly enriched. It will be all the more welcome as hitherto there has existed no comprehensive handbook treating these great epidemic diseases from a didactic point of view. The articles scattered through the reviews, or memoirs buried in the large treatises, did not respond to the need which was felt by the military physician, in France as well as in distant expeditions, of a work which should bring to a common focus a number of questions which were, in general, very imperfectly understood.

The authors review, in succession, the Clinical details, the Epidemiology, and Prophylaxis of *Dysenteries*, *Cholera*, and *Typhus*. In the section dealing with *Prophylaxis*, in particular, will be found practical advice as to the special hygiene possible in the case of large collections of people placed in conditions favourable to the development of these diseases.

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Of all the infections which threaten our wounded men, tetanus is that which, thanks to serotherapy, we are best able to prevent. But serotherapy, when it is late and insufficient, may, on the other hand, tend to create a special type of attenuated and localised tetanus ; in this form the contractions are as a general rule confined to a single limb. This type, however, does not always remain strictly monoplegic ; and if examples of such cases are rare this is doubtless because physicians are not as yet very well aware of their existence.

We owe to MM. Courtois-Suffit and R. Giroux one of the first and most important observations of this new type ; so that no one was better qualified to define its characteristics. This they have done in a remarkable manner, supporting their remarks by all the documents hitherto published, first expounding the characteristics which individualise the other atypical and partial types of tetanus, which have long been recognized.

The preventive action of anti-tetanic serum should not cause us to disregard its curative action, the value of which is incontestable. However, a specific remedy, even when a powerful specific, cannot act upon all the complex elements which constitute a disease ; and tetanus presents itself, in the first place, as an affection of the nervous system. To contend with it, therefore, a symptomatic medication should come to the aid of a pathogenic medication.—*Professor Widal.*

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# SYPHILIS AND THE ARMY

By G. THIBIERGE, Physician of the Hôpital Saint-Louis. Edited by C. F. MARSHALL, F.R.C.S. Price, 6*s*. net. Postage 5*d*. extra.

It seemed, with reason, to the editors of this series that room should be found in it for a work dealing with syphilis considered with reference to the army and the present war.

The frequency of this infection in the army, among the workers in munition factories, and in the midst of the civil population where this is in contact with soldiers and mobilized workers, makes it, at the present time, a true epidemic disease, and one of the most widespread of epidemic diseases.

Dr. Thibierge, whose previous labours guarantee his peculiar competence in these difficult and important questions, has, in writing this manual, very notably assisted in this work.

But the treatment of syphilis has, during the last six years, undergone considerable modifications ; the new methods are not yet very familiar to all physicians ; and certain details may no longer be present to their minds. It was therefore opportune to survey the different methods of treatment, to specify their indications, and their occasionally difficult technique, which is always important if complications are to be avoided. It was necessary before all to state precisely and to retrace, for all those who have been unable to follow the recent progress of the therapeutics of venereal diseases, the characters and the diagnostic elements of the manifestations of syphilis.

Of late years, moreover, new methods of examination have entered into syphilitic practice, and these were such as to merit exposition while the old elements of diagnosis were recalled to the memory.

In short, this little volume contains those essentials which will enable the physician to accomplish the *entire* medical portion of his anti-syphilitic labours ; it will also provide him with the elements of all the medical and extra-medical advice which he may have to give the civil and military authorities in order to arrive at an effective prophylaxis of this disease.

It is therefore a real practical guide, a *vade-mecum* of syphiliography for the use of civil or military physicians.

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By Drs. H. BOURGEOIS, Oto-rhino-laryngologist to the Paris hospitals, and SOURDILLE, former interne of the Paris hospitals. Edited by J. DUNDAS GRANT, M.D., F.R.C.S. (Eng.); Major, R.A.M.C., President, Special Aural Board (under Ministry of Pensions). With many illustrations in the text and full-page plates. Price, 6*s*. net. Postage 5*d*. extra.

This work presents the special aspects of inflammatory affections of the ear and deafness, as they occur in active military service. The instructions as to diagnosis and treatment are intended primarily for the regimental medical officer. The sections dealing with medical reports (*expertises*) on the valuation of degrees of disablement and claims to discharge, gratuity or pension, will be found of the greatest value to the officers of invaliding boards.

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# MALARIA :
## Clinical and Hæmatological Features. Principles of Treatment.

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